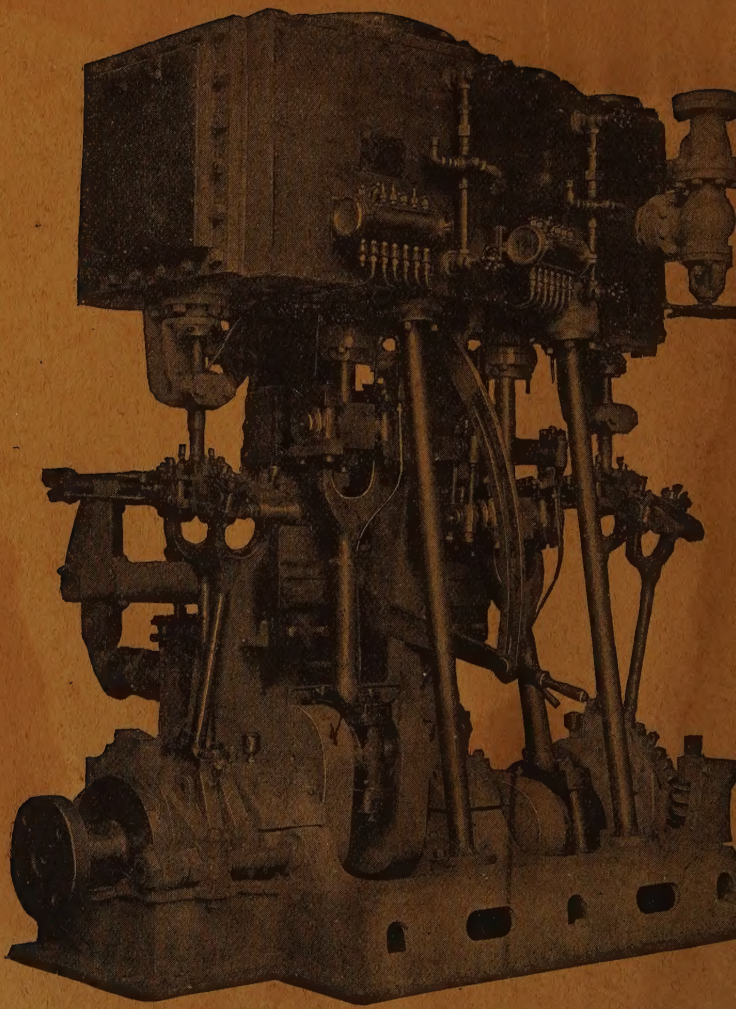
MARINE
ENGINEERING

Gordon Hamilton 3
S.S. City of Gonyebis 3
Firing & oiling

Jo. Halldorson



Fore and Aft Compound Marine Engine

Built for Department of Naval Service, Canada, by Vulcan Iron Works, Jersey
from designs of R. R. Roane, M. E. Cylinders 12″ and 24″ diameter by 16″ stroke, 140 po
steam pressure. Pumps driven off *h. p.* cross head; 9″ air pump; 8″ circulating pum
bilge pump; 2″ feed pump; stroke of pumps 8″; shifting link motion hand reverse; *h. p.* p
valve; *l. p.* slide valve; 150 *r.p.m.* 200 horse power.

AUDELS
NEW
MARINE ENGINEERS
GUIDE
A PRACTICAL TREATISE
ON
MARINE ENGINES, BOILERS
AND
AUXILIARY MACHINERY

INCLUDING

THEORY AND PRACTICE OF THE STEAM TURBINE—ELECTRICITY—ELECTRIC SHIP PROPULSION—REFRIGERATION—OIL FUEL—GASOLINE, OIL AND DIESEL ENGINES—GAS PRODUCERS—MATHEMATICS ON APPROVED RULES FOR CALCULATING THE SAFETY VALVE—HORSE POWER—CAPACITY OF COAL BUNKERS, TANKS, ETC.

AND

BREAKDOWNS AND REPAIRS AT SEA

ALSO

U.S. GOVERNMENT RULES AND REGULATIONS REGARDING ENGINEERS' LICENSES

BY

THEO. LUCAS, M.E. FRANK D. GRAHAM, B.S., M.S., M.E.
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PREFACE

With the advent of the Great War has come the urgent call for ships, ships—more ships.

With this call for ships—brings the demand for the men to operate the engines, boilers, and auxiliary machinery of this vast Naval and Merchant Marine—and to assist these men we issue this book—

In its preparation four things have been kept constantly in view by the authors:

First, that the book should be of use to the practical student.

Second, that it should be plain.

Third, that it should deal thoroughly with the fundamental principles of engineering.

Fourth, that it should explain in detail standard construction.

The book consists of four principal divisions:

1. *Theory*
2. *Construction*
3. *Operation*
4. *Repair.*

The practical man, be he chief engineer, assistant, oiler or fireman, needs, in justice to himself, to have a certain amount of book knowledge to add to the personal experience he is gaining, day by day and year by year, from his immediate surroundings.

Being employed almost without cessation, book learning is a knowledge that has to be obtained in nooks and corners and

in fragments of time, hence, the simplest division possible o the contents of the book has been adopted—that of ***Questio and Answer.*** By this system each subject paragraph is com plete in itself, so that a single one learned in a day will in th end compass the whole subject and prove the value of the book

Again, in this active age, especially in a line that calls fo service day and night, and often seven days in the week, wha is printed must be in clear and simple terms or it will not b read, much less studied.

Of still more importance, the mechanical man should kno the elements or first principles of his profession, for engineerin is less a trade than a profession—one of trust and responsibilit concerning life and property.

If, through the pages of this book, the authors can add anythi to your general knowledge or help you, then they shall consid their purpose accomplished.

Four Cylinder Triple Expansion Engine

Built by Seabury. Cylinders 10½×16½×18½×11 stroke. 1,200 horse power, illustrating open column frame with diagonal and transverse bracing, built up bed plate and self contained thrust bearing; an example of light weight construction for high speed steam yachts.

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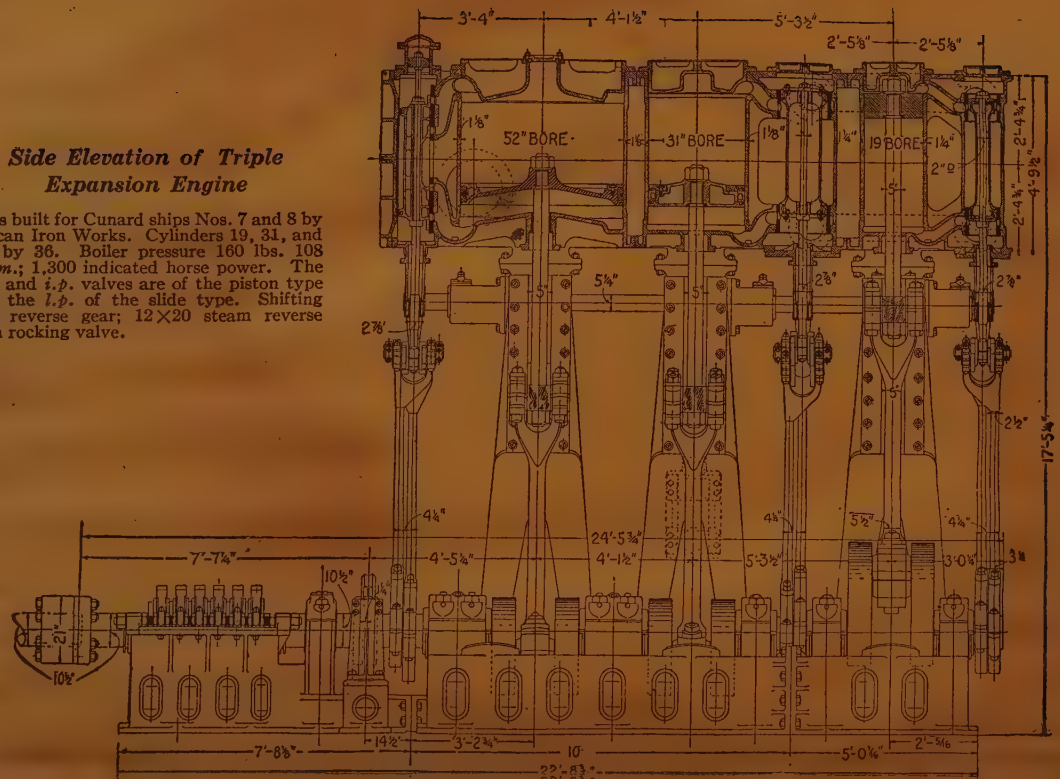
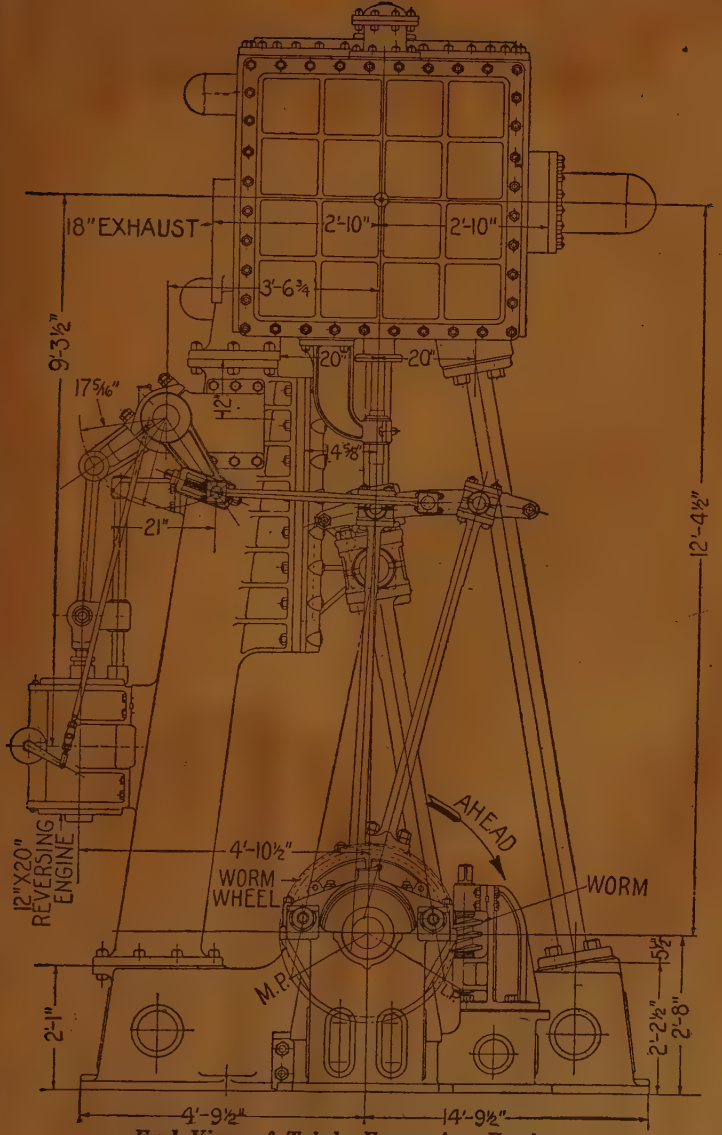


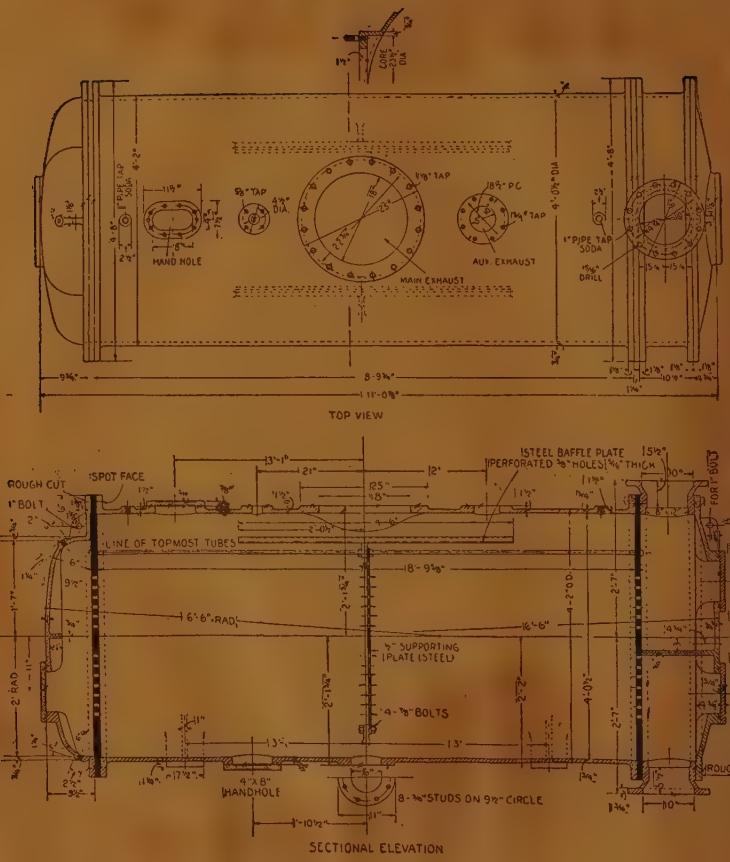
Side Elevation of Triple Expansion Engine

As built for Cunard ships Nos. 7 and 8 by Vulcan Iron Works. Cylinders 19, 31, and 52, by 36. Boiler pressure 160 lbs. 108 *r.p.m.*; 1,300 indicated horse power. The *h.p.* and *i.p.* valves are of the piston type and the *l.p.* of the slide type. Shifting link reverse gear; 12×20 steam reverse with rocking valve.



End View of Triple Expansion Engine

Described in detail and further illustrated on opposite page.



Top and Side Sectional Views of Surface Condenser

Built for Cunard ships 7 and 8 and U. S. Shipping Board Emergency Fleet Ships 9 to 2 by Vulcan Iron Works. 2,000 sq. ft. cooling surface, cast iron shell and heads; naval bronz tube sheets ¾" O. D.; brass tubes 9 feet long with standard ferrules and Allen packing.

MATHEMATICS

USEFUL TO THE ENGINEER AND MACHINIST.

The following abridgment of matters often referred to in elementary books on mechanical science, is here inserted for the convenience of reference. Many of these rules and examples are given to refresh the memory, it being taken for granted that the reader has already acquainted himself with the principles of most of them.

They will be found serviceable, both as a convenience of reference, and to give some further insight into the subjects on which they treat.

A *Number* is a unit or collection of units; as two, five, six feet, etc.

An *Integer* is a number that represents whole things.

An *Abstract Number* is one which does not refer to any particular object.

A *Concrete Number* is a number used to designate objects or quantities.

An *Odd Number* is a number which cannot be divided by two.

An *Even Number* can be exactly divided by two.

QUOTATION.—"Calculation is the mind of business. A readiness in calculation gives a man great advantages over his less experienced neighbor.

Factors of a number are those numbers which, when multiplied together, make that number.

A *Prime Number* is a number exactly divisible by one.

A *Composite Number* is a number which can be divided by other integers besides itself and one.

An *Exact Divisor* of a number is a whole number that will divide that number without a remainder.

The *Greatest Common Divisor* of two or more numbers is the greatest number that will divide each of them exactly.

A *Multiple* of a number is any number exactly divisible by that number.

The first of the nine Arabic characters are called digits, from the Latin word *digitus*, a finger, owing to the fact that the ancients reckoned by counting the fingers.

Measures are of seven kinds: 1. *Length.* 2. *Surface or area.* 3. *Solidity or capacity.* 4. *Weight, or force of gravity.* 5. *Time.* 6. *Angles.* 7. *Money, or value.*

There are various characters or marks used in arithmetical computations, to denote several of the operations and propositions, the chief of which are as follows:

$=$ *Equal to.* The sign of equality; as 100 cents$=$$1, signifies that 100 cents are equal to one dollar.

$-$ *Minus*, or *less.* The sign of subtraction; as $8-2=6$; that is, 8, less 2, is equal to 6.

$+$ *Plus*, or *more.* The sign of addition; as $4+5=9$; that is, 4, added to 5, is equal to 9.

$\times$ *Multiplied by.* The sign of multiplication; as $6\times6=36$; that is, 6 multiplied by 6 is equal to 36.

$\div$ *Divided by.* The sign of division; as $12\div3=4$; that is, 12, divided by 3, is equal to 4.

: is to
: : so is
: to
} The signs of proportion; as 2 : 4 : : 8 : 16; that is, as 2 is to 4, so is 8 to 16.

$7-2+5=10$. Shows that the difference between 7 and 2, added to 5, is equal to 10.

^{2} added to a number, signifies that the number is to be *squared;* thus: 6^2 means that 6 is to be multipled by 6.

^{3} added to a number, signifies that the number is to be *cubed;* thus: $5^3=5\times5\times5=125$. The *index*, or *power*, is the number of times a number is to be multiplied by itself, and is shown by a small figure placed at the right of the number to be raised, and a little elevated.

The parenthesis signifies that all the numbers within it are to be taken together; as $(7+4)-3=8$; or, $5\times(6-4)=10$.

NOTATION AND NUMERATION.

Figures have two values, Simple and Local. The simple value of a figure is its value when standing in units' place. The local value of a figure is the value which arises from its location.

Notation in Arithmetic is the *writing down* of figures to express a number or numbers, and *Numeration* is *the reading of numbers* already written.

There are nine figures—1, 2, 3, 4, 5, 6, 7, 8 and 9 used in arithmetic, and the 0 (naught) to represent nothing.

The number 1 is called *the unit.* The number 9 is a collection of nine of these units.

By means of these 10 figures any number can be represented. When one of the figures stands by itself, it is called a *unit;* but if two of them stand together, the right hand one is still called a unit, but the left hand one is called *tens;* thus, 79 is a collection of 9 units and 7 sets of ten units each, or of 9 units and 70 units, or of 79 units, and is read as seventy-nine.

If three of them stand together, then the left hand one is called *hundreds;* thus 279 is read two hundred and seventy-nine.

Names of periods.	Billions.			Millions.			Thousands.			Units.				Thousandths.		
Order of Units.	Hundred-billions.	Ten-billions.	Billions.	Hundred-millions.	Ten-millions.	Millions.	Hundred-thousands.	Ten-thousands.	Thousands.	Hundreds.	Tens.	Units.	Decimal point.	Tenths.	Hundredths.	Thousandths.
	8	7	6,	5	4	3,	2	0	1,	2	8	2,	.	4	8	9

The number in the table is read eight hundred and seventy-six billion, five hundred and forty-three million, two hundred and one thousand, two hundred and eighty-two, and four hundred and eighty-nine thousandths.

In the table given it will be observed that the long row of figures is divided by commas (,). This is to aid in their ready reading. The first set is called units, the second thousands, the third millions, etc.

Beginning at units place, the orders on the right of the decimal point express tenths, hundredths, thousandths, etc.

This system is called Arabic Notation from the fact that it was introduced into Europe in the 10th century by the Arabs.

Its great law is that ten units in any order make one unit of the next order.

And the moving a figure one place either increases or diminishes its value by the uniform scale of ten; hence it is called the Decimal System from the Latin word *decem*, which means *ten*.

The *Roman Notation* is the method of notation by letters, and is illustrated as follows:

I,	V,	X,	L,	C,	D,	M,
1,	5,	10,	50,	100,	500,	1,000

Repeating a letter repeats its value; thus, I=1, II=2.

Placing a letter of less value before one of greater value diminishes the value of the greater by the less; thus, IV=4, IX=9, XL=40.

Placing the less after the greater increases the value of the greater by that of the less; thus, VI=6, XI=11, LX=60.

Placing a horizontal line over a letter increases its value a thousand times; thus, $\overline{\text{IV}}$=4,000, $\overline{\text{M}}$=1,000,000.

To attain the habit of quick calculation without the aid of a slate and pencil, Dr. Abbott recommends that the learner seize on "every circumstance which occurs in his reading, where reckoning is required, and, if possible, stop at once and compute it. Or, if not, let the place be marked, and, at the first leisure moment let him turn to it and make the estimates."

ROMAN TABLE.

I	denotes	One.	XVII	denotes	Seventeen.
II	"	Two.	XVIII	"	Eighteen.
III	"	Three.	XIX	"	Nineteen.
IV	"	Four.	XX	"	Twenty.
V	"	Five.	XXX	"	Thirty.
VI	"	Six.	XL	"	Forty.
VII	"	Seven.	L	"	Fifty.
VIII	"	Eight.	LX	"	Sixty.
IX	"	Nine.	LXX	"	Seventy.
X	"	Ten.	LXXX	"	Eighty.
XI	"	Eleven.	XC	"	Ninety.
XII	"	Twelve.	C	"	One hundred.
XIII	"	Thirteen.	D	"	Five hundred.
XIV	"	Fourteen.	M	"	One thousand.
XV	"	Fifteen.	$\overline{X}$	"	Ten thousand.
XVI	"	Sixteen.	$\overline{M}$	"	One million.

ADDITION.

Uniting two or more numbers or groups of objects of the same kind into one is called Addition, and the number obtained by adding is called the Sum.

RULE.—I. *Write the numbers to be added so that like orders of units stand in the same column.*

II. *Commencing with the lowest order, or at the right hand, add each column separately, and if the sum can be expressed by one figure, write it under the column added.*

III. *If the sum of any column contains more than one figure, write the unit figure under the column added, and add the remaining figure or figures to the next column.*

EXAMPLES FOR PRACTICE.

7,060	248,124	13,579,802
9,420	4,321	93
1,743	889,866	478,652
4,004	457,902	87,547,289
22,227 Ans.		

SUBTRACTION.

Subtraction is taking one number from another.

As in addition, care must be taken in placing the units under the units. the tens under the tens, etc.

The answer is called the remainder or the the difference.

RULE.—*Write down the sum so that the units stand under the units, the tens under the tens, etc., etc.*

Begin with the units, and take the under from the upper figure, and put the remainder beneath the line.

But if the lower figure is the larger, add ten to the upper figure, and then subtract and put the remainder down—this borrowed ten must be deducted from the next column of figures, where it is represented by 1.

EXAMPLES FOR PRACTICE.

892	89,672	89,642,706
46	46,379	48,765,421
846 remainder.		

MULTIPLICATION.

Multiplication is finding the amount of one number increased as many times as there are units in another.

The number to be multiplied or increased is called the *Multiplicand.* The *Multiplier* is the number by which we

multiply. It shows how many times the multiplicand is to be increased. The answer is called the *Product*.

The sign of multiplication is × and is read "times" or multiplied by; thus 6×8 is read, 6 times 8 is 48, or, 6 multiplied by 8 is 48.

RULE.—*Place the unit figure of the multiplier under the unit figure of the multiplicand, and proceed as in the following:*

EXAMPLE.

Multiply 846 by 8; and 478,692 by 143.

Arrange them thus:

	487,692
	143
846	
8	1463076
	1950768
6,768	487692
	69,739,956

If the multiplier has ciphers at its end, place it as in the following:

EXAMPLE.

Multiply 83567 by 50; and 898 by 2800.

	898
	2800
83567	718400
50	1796
4,178,350	2,514,400

NOTE.—Multiplication is a word derived from the Latin, *multiplicatio*, signifying the act of increasing numbers. In arithmetic, a rule or operation by which any given number may be repeated or added to itself any number of times proposed.—WEBSTER.

The product and the multiplicand must be in like numbers. Thus, 10 times 8 gallons of oil must be 80 gallons of oil. 4 times 5 dollars must be 20 dollars; *hence the multiplier must be the number and not the thing to be multiplied.* In finding the cost of 6 tons of coal at 7 dollars per ton the 7 dollars are taken 6 times, and not multiplied by six tons.

DIVISION.

Division is the separating into parts, or the rule by which is found how many times one number or quantity is contained in another.

The number divided is called the *dividend.* The number by which it is divided is called the divisor. The result obtained is called the *quotient.* The part of the dividend which remains after the operation is completed is called the *remainder.*

RULE.—*Put the dividend down with the divisor to the left of it, with a small curved line separating it, as in the following:*

Divide 7,865,432 by 6.

6)7,865,432

1,310,905—2

Here at the last we have to say 6 into 32 goes 5 times and 2 over; always place the number that is over as above, separated from the quotient by a small line, or else put it as a fraction, thus, $\frac{2}{6}$, the top figure being the remainder and the bottom figure the divisor, when it should be put close to the quotient; thus—1,310,905$\frac{2}{6}$.

To divide by any number up to 12 with a cipher or ciphers after it, as 20, 70, 90, 500, 7,000, etc.

Place the sum down as in the last example, then mark off from the right of the dividend as many figures as there are ciphers in the divisor; also mark off the ciphers in the divisor; then divide the remaining figures by the number remaining in the divisor, thus:

EXAMPLE.

Divide 9,876,804 by 40.

40)9,876,804

246,920—4

The 4 cut off from the dividend is put down as a remainder, or it might have been put down as $\frac{4}{40}$ or $\frac{1}{10}$.

To divide by any number not included in the last three cases. This is common long division, as it is called.

RULE.—*Write the divisor at the left of the dividend and proceed as in the following:*

EXAMPLE.

Divide 726,981 by 7,645.

7,645)726981(95

68805

38931

38225

706 Ans. $95\frac{706}{7645}$.

To divide by 25.

RULE.—*Multiply the dividend by 4 and divide the product by 100 by cutting off two figures from the right, as follows:*

EXAMPLE.

4574
4
1|00)182.96

RULE FOR PROVING.—*Division may be proved by multiplying the Quotient by the integral part of the Divisor, and adding to the product the remainder, if there is any.*

1, Multiplying the dividend, or dividing the divisor by any number, multiplies the quotient by the same number.

2, Dividing the dividend, or multiplying the divisor by any number, divides the quotient by the same number.

3, Dividing or multiplying both the dividend and divisor by the same number does not change the quotient.

DECIMALS.

A decimal fraction derives its name from the Latin *decem*, "ten," which denotes the nature of its numbers, representing the parts of an integral quantity, divided into a tenfold proportion. It has for its denominator a *unit*, or whole thing, as a gallon, a pound, a yard, etc., and is supposed to be divided into ten equal parts, called tenths; those tenths into ten equal parts, called hundredths, and so on without end.

The denominator of a decimal being always known to consist of a unit, with as many ciphers annexed as the numerator has places, is never expressed, being understood to be 10, 100, 1000, etc., according as the numerator consists of 1, 2, 3, or more figures. Thus: $\frac{2}{10}$, $\frac{24}{100}$, $\frac{125}{1000}$, etc., the numerators only are written with a dot or comma before them, thus, .2, .24, .125.

The use of a dot (.) is to separate the decimal from the whole numbers.

The first figure on the right of the decimal point is in the place of tenths, the second in the place of hundredths, the third in the place of thousandths, always decreasing from the left towards the right in a tenfold ratio as in the following:

TABLE.

Ascending.											Descending.										
etc., etc.	5	Tens of Millions.	5	Millions.	5	Hundreds of Thousands.	5	Tens of Thousands.	5	Thousands.	5	Hundreds.	5	Tens.	5	Units.	.	Decimal point.	5	Tenths.	5	Hundredths.	5	Thousandths.	5	Ten Thousandths.	5	Hundred Thousandths.	5	Millionths.	5	Ten Millionths.	etc., etc.

A cipher placed on the left hand of a decimal decreases its value in a ten-fold ratio by removing it further from the decimal point. But annexing a cipher to any decimal does not alter its value at all. Thus 0.4 is ten times the value of 0.04, and a hundred times 0.004. But 0.7=0.70=0.700=0.7000, etc., as above remarked.

0.2 is read two-tenths.
0.25 " " twenty-five hundredths.
0.375 " " three hundred and seventy-five thousandths.
0.1876 " " one thousand eight hundred and seventy-six ten thousandths, and so on.

Mixed numbers consist of a whole number and a decimal, as 4.25 and 3.875.

To reduce a fraction to a decimal.

RULE.—*Annex decimal ciphers to the numerator, and divide by the denominator, pointing off as many decimal places in the quotient as there are ciphers annexed.*

EX.—Reduce $\frac{3}{4}$ to a decimal.

4)3.00

.75

To reduce a decimal to a fraction.

RULES.—1, *Omit the decimal point;* 2, *Supply the proper denominator;* 3, *Reduce the fraction to its lowest terms.*

EX.—Reduce .075 to an equivalent fraction.

$.075 = \frac{75}{1000} = \frac{3}{40}$.

NOTE.—The denominator of a decimal fraction is understood, and is 1 with as many ciphers annexed as there are figures in the decimal; thus

Form of common fraction.		Form of decimal fraction.		
$\frac{7}{10}$	is written	.7	and is read	seven tenths.
$\frac{8}{100}$	" "	.08	" "	eight hundredths.
$\frac{16}{1000}$	" "	.016	" "	sixteen thousandths.

ADDITION OF DECIMALS.

RULE.—*Arrange the numbers so that the decimal points shall be directly over each other, and then add as in whole numbers, and place the decimal point directly below all the other points.*

FRACTIONS.

$\frac{5}{10}$	is same as	.5	read 5 Tenths.
$\frac{7}{100}$	"	.07	read 7 Hundredths.
$\frac{30}{1000}$	"	.030	read 30 Thousandths.
$\frac{1248}{10000}$	"	.1248	read 1248 Ten Thousandths.
$8\frac{6}{10}$	"	8.6	read 8 and 6 Tenths.
$7\frac{8}{1000000}$	"	7.000008	read 7 and 8 Millionths.
$84\frac{25}{100}$	"	84.25	read 84 and 25 Hundredths.
$5\frac{6}{10000000}$	"	5.0000006	read 5 and 6 Ten Millionths.
480	"	480.	read 480.
		585.5748086	read 585 and 5748086 Ten Millionths.

SUBTRACTION OF DECIMALS.

RULE.—*Place the numbers directly under each other, according to their several values, as in addition; then subtract as in whole numbers, and point off the decimals, as in the last rule.*

EXAMPLE.

Subtract 7.75 from 15.125.

15.125
7.75

7.375 remainder.

MULTIPLICATION OF DECIMALS.

RULE.—*Place the factors under each other, and multiply them together as in whole numbers. Then point off as many figures from the right hand of the product as there are decimal places in both factors, observing, if there be not enough, to annex as many ciphers to the left hand of the product as will supply the deficiency.*

EXAMPLE.

Multiply 3.625 by 2.75.

$3.625 \times 2.75 = 9.96875$. Ans.

DIVISION OF DECIMALS.

RULE.—*Prepare the decimal as directed for multiplication; divide as in whole numbers; cut off as many figures for decimals in the quotient as the number of decimals in the dividend exceeds the number in the divisor; and if the places in the quotient be not so many as the rule requires, supply the deficiency by annexing ciphers to the left hand of the quotient.*

NOTES.—If the number of figures in the quotient is less than the number of decimal places to be pointed off, supply the deficiency by prefixing ciphers.

2. If the divisor contains more decimal places than the dividend, before dividing make them equal by annexing ciphers to the dividend. If necessary to continue the division, more ciphers may be added.

3. If, after dividing all the figures of the dividend, there is a remainder, the division may be continued by annexing ciphers. The ciphers thus annexed must be regarded as decimal places of the dividend.

4. To divide a decimal by 10, 100, 1000, etc., remove the decimal point as many places to the left as there are ciphers in the divisor, prefixing ciphers to the dividend, if necessary.

EXAMPLE IN DIVISION OF DECIMALS.

Divide 173.5425 by 3.75.

```
3.75)173.5425(46.27
     1500
     ----
      2354
      2250
      ----
       1042
        750
        ---
       2925
       2625
       ----
        300
```

RULE OF THREE, OR PROPORTION.

The Rule of Three teaches how to find a fourth proportional term to three given numbers.

The rule of three is either direct or inverse.

When more requires more, or less requires less, it is direct. Thus, 30 cubic inches of cast iron weigh 8 pounds; what will 378 cubic inches weigh?

The proportion in the above case is direct, and the statement must be

30 : 8 : : 378 : 4th term = $100\frac{4}{5}$ lbs. Ans.

When more requires less, or less requires more, the rule is inverse. Thus, if 12 men build a certain quantity of wall in 28 days, in how many days will 8 men perform the same work?

Here the proportion is inverse, and the statement must be

As 8 : 28 : : 12 : 4th term = 42. Ans.

The product of the second and third terms divided by the first, always gives the fourth term.

Three numbers are necessary for a statement; and two of these must contain the supposition and the third the demand.

RULE.—*Of the three given numbers, place that for the third term, which is of the same kind with the answer sought.*

Then consider, from the nature of the question, whether the answer will be greater or less than this term. If the answer is to be greater, place the greater of the two numbers for the second term, and the less number for the first term; but if it is to be less, place the less of the two remaining numbers for the second term and the greater for the first; and in either case multiply the second and third terms together, and divide the product by the first for the answer, which will always be of the same denomination as the third term.

EXAMPLE.

If 40 tons of iron cost $450, what will 130 tons cost?

TONS DOLLS. TONS

40 : 450 : : 130

130

13500

450

4|0)5850|0

1462.5 dollars. Ans.

NOTE.—If the first and second terms contain different denominations, they must both be reduced to the same denomination; and compound numbers to integers of the lowest denomination contained in it.

EVOLUTION OR SQUARE ROOT.

The SQUARE ROOT of a number is one of the two equal factors of a number. Thus, the square root of 25 is 5. $5 \times 5 = 25$.

To find the square root of a number.

RULE.—*Beginning at units' place, separate the given number into periods of two figures each.*

Find the greatest square in the left-hand period, and write its root at the right in the form of a quotient in division. Subtract this square from the left-hand period, and to the remainder annex the next period to form a dividend.

Double the part of the root already found for a trial divisor. Find how many times this divisor is contained in the dividend, exclusive of the right-hand figure, and write the quotient as the next figure of the root. Annex this quotient to the right of the trial divisor to form the complete divisor. Multiply the complete divisor by the last figure of the root, and subtract the product from the dividend.

To the remainder annex the next period, and proceed as before.

When the given number is a decimal, separate the number into periods of two numbers each, by proceeding in both directions from the decimal point.

EXAMPLE.

Find the square root of 186624.

```
    18,66,24(432
    16
83  | 266
    | 249
862 | 1724
    | 1724
```

Proof 432

```
 432
 ---
 864
1296
1728
------
186624
```

Begin at the last figure 4, count two figures, and mark the second as shown in the Example; count two more, and mark the figure, and so on till there are no more figures; take the figures to the left of the last dot, 18, and find what number multiplied by itself will give 18; there is no number that will do so, for $4\times4=16$, is too small, and $5\times5=25$, is too large; we take the one that is too small, viz., 4, and place it in the quotient, and place its square 16 under the 18, subtract and bring down the next two figures 66.

To get the divisor multiply the quotient 4 by $2=8$, place the 8 in the divisor, and say 8 into 26 goes 3 times, place the three after the 4 in the quotient, and also after the 8 in the divisor; multiply the 83 by the 3 in the quotient, and place the product under the 266 and subtract, then bring down the next two figures, 24.

To get the next divisor, multiply the quotient 43 by $2=86$; see how often 8 goes into 17—twice; place the 2 after the 43 of the quotient, and also after the 86 of the divisor; multiply the 862 by the 2, and put it under the 1724, then subtract. Answer, 432.

In expressing the square root it is customary to u simply the mark ($\surd$), the 2 being understood.

All roots as well as powers of *one* are 1, as $\surd 1 = 1$.

EXAMPLE.

Find the square root of 588.0625.

$$
\begin{array}{r|l}
 & 5,88.06,25(24.25 \\
 & 4 \\
\hline
44 & 188 \\
 & 176 \\
\hline
482 & 1206 \\
 & 964 \\
\hline
4845 & 24225 \\
 & 24225
\end{array}
$$

In a decimal quantity like the above, the marking differs from the former example. Instead of counting tw from right to left, we begin at the decimal point and cou twos toward the left and toward the right. The rest of t work is similar to the other examples.

Notice, that when the .06 is brought down, the figure f a quotient is a decimal.

To familiarize oneself with the extracting of the squa root, it is well, first, to square a number and then work bac ward according to the examples here given, and by long a frequent practice become expert in the calculation. But first working square root, it is undoubtedly better to secure t services of a teacher.

INVOLUTION

Is the raising a number (called the root) to any power. The powers of a number are its square, cube, 4th power, 5th power, etc.

$2\times2=4$	4 is the square or 2d power of 2.
$2\times2\times2=8$	8 is the cube or 3d power of 2.
$2\times2\times2\times2=16$	16 is the 4th power of 2.
Etc.	Etc.

RULE.—*To square a number multiply it by itself.*

EX.—What is the square of 27 (written 27^2)?

27
27

189
54
---
729 Answer.

RULE.—*To cube a number, multiply the square of the number by the nuuber again.*

EX.—What is the cube of 50 (written 50^3)?

50
50

2500 the square
50

125000 the cube.

A *power* of a quantity is the product arising from multiplying the quantity by itself one or more times. When the quantity is taken *twice* as a factor the product is called the *second* power; when taken *three* times, the *third* power, and so on.

Signs that Represent the Roots of Numbers.

The sign common to all roots is $\surd$ or $\surd\overline{\ }$ and is known as the radical sign. If we require to express the square root of a number we simply put this sign before it, as $\surd 16$, but if the number is made up of two or more terms, then we express the square root by the same in front, but with a line as far as the square root extends, as $\surd\overline{9+7}$ or $\surd\overline{4(19+6)}$.

The cube root is expressed by the same sign, with a 3 in the elbow, as $\sqrt[3]{8}$ or $\sqrt[3]{\overline{7\ (100-51)}}$.

All other roots in the same manner, the number of the root being put instead of the 3. As fifth root $\sqrt[5]{}$, and sixth root $\sqrt[6]{}$, etc.

In the above examples, $9+7=16$, and the square root of 16 is 4.

The $4\ (19+6)=4\times 25=100$, and the square root of 100 is 10.

The other way of expressing that the root is required is by putting a fraction after and above the quantity, as $16^{\frac{1}{2}}$, which means the square root of 16, $(19+17)^{\frac{1}{2}}$, or $\{4\ (19+6)\}^{\frac{1}{2}}$ all of which means the square root of the quantities to which they are attached.

The cube root, 4th root, 5th root, etc., are written in the same way, as $729^{\frac{1}{3}}=9$; $256^{\frac{1}{4}}=4$; $3125^{\frac{1}{5}}=5$, etc.

Signs Representing the Powers of Numbers.

6^2 is equal to $6\times 6=36$; that is, 36 is the square of 6.

5^3 is equal to $5\times 5\times 5=125$; that is, 125 is the cube of 5.

4^4 is equal to $4\times 4\times 4\times 4=256$; that is, 256 is the 4th power of 4.

The power and the root are often combined, as $4^{\frac{3}{2}}$; this is read as the square root of 4 cubed. So the numerator figure represents the power, and the denominator figure represents the root. In this case the square root of 4 is 2, and the cube of 2 is $2\times2\times2=8$. Answer.

Perhaps the most common form that the student will meet with this sign is in the following:

$8^{\frac{2}{3}}$, which is read the cube root of 8 squared. Now, 8 squared=64, and the cube root of 64 is 4. Answer.

Find the value of $20^{\frac{3}{2}}$.

20 cubed=8000, and square root of 8000=89.4, etc.

EXAMPLE.

What is the value of $\frac{8^{\frac{2}{3}}+81^{\frac{1}{2}}}{3^{\frac{3}{2}}}$?

$8^{\frac{2}{3}}=\sqrt[3]{8^2}=\sqrt[3]{64}=4$; $81^{\frac{1}{2}}=9$; $3^{\frac{3}{2}}=\sqrt{3^3}=\sqrt{27}=5.2$ nearly.

Hence, $\frac{4+9}{5.2}=\frac{13}{5.2}=2.5$ or $2\frac{1}{2}$. Answer.

( ) are called *brackets*, and mean that all the quantities within them are to be put together first; thus, $7(8-6+4\times3)$ means that 6 must be subtracted from 8=2, and 4 times 3=12 added to this 2=14; and then this 14 is to be multiplied by 7=98.

"To the young man who would rise in the world I have but one word of caution—be thorough."—R. C. OGDEN.

GEOMETRICAL CONSTANTS.

CONSTANT.

This word in mathematics signifies remaining unchanged or invariable, as a quantity or a force.

CIRCLES.

Circumference	= Diameter × 3.1416.
Circumference	= Radius × 6.2832.
Radius	= Circumference ÷ 6.2832.
Radius	= Circumference × .1592.
Radius	= $\sqrt{\text{Area}} \div 3.1416$.
Radius	= $\sqrt{\text{Area}} \times .5642$.
Diameter	= Circumference ÷ 3.1416.
Diameter	= Circumference × .3183.
Diameter	= $\sqrt{\text{Area}} \div .7854$.
Diameter	= $\sqrt{\text{Area}} \times 1.1284$.
Area	= Radius square × 3.1416.
Area	= Diameter square × .7854.

Side of inscribed square	= Diameter × .707
Side of equal square	= Diameter × .886
Side of inscribed equilateral triangle	= Diameter × .860

SPHERES.

Surface	= Diameter square × 3.1416.
Surface	= Circumference square × .3183.
Volume	= Diameter cubed × .5236.
Volume	= Circumference cubed × .0169.
Diameter	= $\sqrt{\text{Surface}} \times .5642$.
Diameter	= $\sqrt[3]{\text{Volume}} \times 1.2407$.
Radius	= $\sqrt{\text{Surface}} \times .2821$.

Radius	$= \sqrt[3]{\text{Volume}} \times .6204.$
Circumference	$= \sqrt{\text{Surface}} \times 1.7725.$
Circumference	$= \sqrt[3]{\text{Volume}} \times 3.8978.$
Side of inscribed cube	= Diameter $\times$ .5774.
Side of inscribed cube	= Radius $\times$ 1.1547.

ROOTS, ETC.

Diagonal of square	= Side $\times$ 1.4142.
Square root of 2	= 1.4142.
Side of square	= Diagonal $\times$ .7071.

THE METRIC SYSTEM.

In the metric or French system of weights and measures, the *Meter* is the basis of all the units which it employs. The *Meter* is the unit of length, and is equal to one ten-millionth part of the distance measured on a meridian of the earth from the equator to the pole, and equals about 39.37 inches, or $39\frac{1}{3}$ inches nearly.

The standard meter is a bar of platinum carefully preserved at Paris. Exact copies of the meter and the other units have been procured by the several nations (including the United States) that have legalized the system.

In this system weights and measures are increased or decreased by the following words prefixed to them:

Milli	expresses the	1,000th part.
Centi	" "	100th "
Deci	" "	10th "
Deka	"	10 times the value.
Hecto	"	100 " " "
Kilo	"	1,000 " " "

THE METRIC SYSTEM.

	1 Millimeter...($\frac{1}{1000}$ of a meter)	=	.03937 *in.*
10 *mm.* =	1 Centimeter..($\frac{1}{100}$ of a meter)	=	.3937 *in.*
10 *cm.* =	1 Decimeter...($\frac{1}{10}$ of a meter)	=	3.937 *in.*
10 *dm.* =	1 METER.....(1 meter)	=	39 37 *in.*
10 *m.* =	1 Dekameter ..(10 meters)	=	32.8 *ft.*
10 *Dm.* =	1 Hectometer..(100 meters)	=	328.09 *ft.*
10 *Hm.* =	1 Kilometer...(1000 meters)	=	.62137 *mile.*

FORMULAS.

A *rule* is a positive method prescribed for performing any operation and producing a certain result, as, a rule for extracting square root, elsewhere given.

A *formula* is a rule or principle expressed in letters and arithmetical signs; the letters and signs are called symbols the *quantities* are expressed by letters and the operations upon them are indicated by the signs; by means of two or three letters and signs we can express a long rule, and this is the object of all formulæ.

Any letter may be used for representing a quantity; but generally it is better to use the first letter of the name of the quantity when this can be done without ambiguity.

Whenever letters are used each formula should be accompanied by a clear statement of the significance of each letter.

The advantages of formulas and a knowledge of how to read them are worth the time given to learn the process and so dispel the notion that they are difficult to read and of little practical value.

NOTE.—A gramme is the weight of a cubic centimeter of distilled water; a decigramme contains $\frac{1}{10}$ of a gramme; a dekagramme contains 10 grammes.

The simplicity of formulas, the briefness with which a rule can be stated with symbols, and the advantage of seeing the whole operation at a glance, commends the use of formulas; after one has become familiar with them he will greatly prefer them to the ordinary rules.

EX.—FORMULA FOR DETERMINING STRENGTH OF BOILERS.

$$P = \frac{t \times T}{D} \times 2$$

P=bursting pressure; t=thickness of plate; T=tensile strength of the iron or steel; D=diameter of shell.

Suppose the boiler to be 48 inch diameter of shell, of $\frac{1}{4}$-inch plate, having a tensile strength of 60,000 pounds per square inch of cross section, the rupturing pressure would be

$$P = \frac{.25 \times 60{,}000}{48} \times 2 = 625 \text{ pounds.}$$

If the boiler is single riveted, it would be limited to $\frac{1}{6}$ of the maximum strength, or 104.16 pounds. With double rivets and holes drilled instead of punched, a working pressure of 125 pounds might be allowed.

EX.—FORMULA FOR HORSE POWER OF ENGINES.

$$\frac{P\ A\ T}{33{,}000}$$

P being the mean effective pressure in pounds per square inch, A the piston area in square inches, and T the piston travel in feet per minute.

NOTE.—These examples of formulas are perhaps the simplest and yet the most frequently used of any printed, and it would be well for the student to commit them to memory.

THE CIRCLE.

The circle is a plane figure comprehended by a single curved line, called its *circumference*, every part of which is equally distant from a point called the *center*. Of course, all lines drawn from the center to the circumference are equal to each other.

.7854

"Why is the decimal .7854 used to ascertain the area of a circle or round opening?" is a question frequently asked. Now, if you will divide a square inch into 10,000 equal parts, then describe a circle one inch in diameter and divide that into ten-thousandths of an inch, you will find that you have 7854 of such squares, each one thousandth of an inch; hence the decimal .7854 is used as a "constant" or multiplier, after squaring the diameter, and the result is the area of the circle.

3.1416

The Greek letter π, called pi, is used to represent 3.1416, nearly. Another approximate proportion is $\frac{22}{7}$, and another still nearer is $\frac{355}{113}$.

PARTS OF A CIRCLE.

The circumference of a circle is supposed to be divided into 360 degrees or divisions, and as the total angularity about the center is equal to four right angles, each right angle contains 90 degrees, or 90°, and half a right angle contains 45°. Each degree is divided into 60 minutes, or 60′; and, for the

sake of still further minuteness of measurement, each minute is divided into 60 seconds, or 60″. In a circle there are, therefore, 360×60×60=1,296,000 seconds.

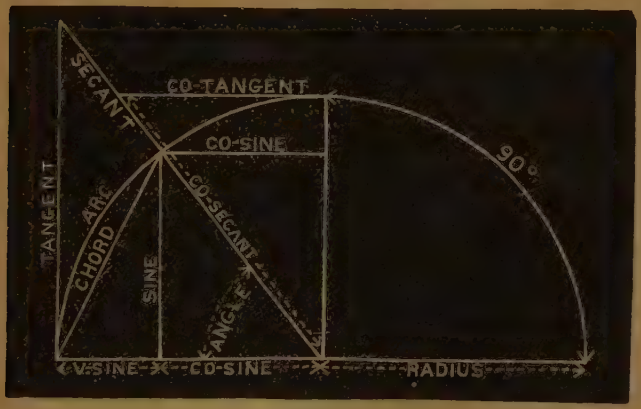


Fig. 3.

The above diagram exemplifies the relative positions of the

Sine, Tangent

Cosine, Cotangent,

Versed sine, Secant, and

Cosecant

of an angle.

NOTE.—The circumferences of all circles contain the same number of degrees, but the greater the radius the greater the absolute measures of a degree. The circumference of a fly-wheel or the circumference of the earth have the same number of degrees; yet the same number of degrees in each and every circumference is the measure of precisely the same angle.

USEFUL MEASUREMENTS.

To find the length of the curve line, called the circle; that is, to find the circumference of a circle.

RULE.—*Multiply* 3.1416 *by the diameter.*

Fig. 4.

EX.—What is the circumference of a circle whose diameter is 3 inches?

$$\begin{array}{r} 3.1416 \\ \times\quad 3 \\ \hline \end{array}$$

Answer, 9.4248

To find the diameter of a circle.

RULE.—(1) *Multiply the circumference by* 7 *and divide by* 22; or (2) *Divide the circumference by* 3.1416.

EX.—A pulley has a circumference of 50.30″; find its diam.?

$$\frac{50.30 \times 7}{22} = 16'' \text{ diameter.} \quad \text{Answer.}$$

To find the area of a circle.

RULE.—*Multiply the square of the diameter by* .7854.

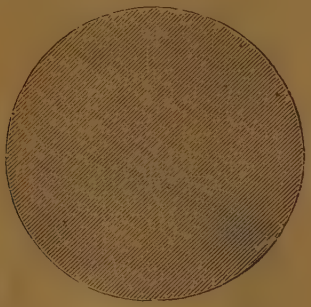


Fig. 5.

EXAMPLE.

The diameter of a circle is 3 inches; find its area.

3	.7854
3	9
9	Answer, 7.0686 square inches.

EXAMPLE.

The diameter of a circle is 3.5 inches; find the area.

3.5	.7854
3.5	12.25
175	39270
105	15708
	15708
12.25	7854
	Answer, 9.621150 square inches.

To find the solidity of a cylindrical ring.

RULE.—*To the thickness of the ring, add the inner diameter; and this sum being multiplied by the square of the thickness, and the product again by* 2.4674, *will give the solidity.*

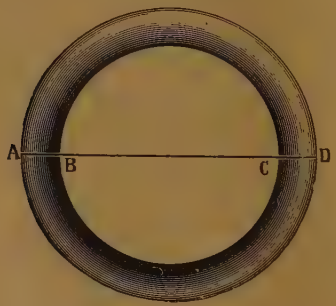


Fig. 6.

EXAMPLE.

What is the solidity of a cylindrical ring whose thickness *A B* or *C D* is 6, and the inner diameter *B C* 20 inches?

Here $(20+6)\times 6^2\times 2.4674=26\times 36\times 2.4674=936\times 2.467$
$=2309.4864$ inches, the solidity required.

The surface of a cylindrical ring may be found by the following rule: To the thickness of the ring add the inner diameter; and this sum being multiplied by the thickness, and the product again by 9.8696, will give the surface required.

To find the sectional area of a ring or pipe.

RULE.—*From the area of the greater circle subtract that of the lesser.*

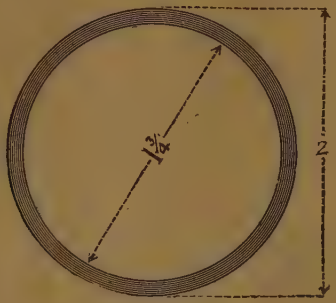


Fig. 7.

EX.—A pipe has an external diameter of 2″ and an internal diameter of $1\frac{3}{4}$″; find its sectional area in square inches.

Thus area of $2''=2^2 \times .7854=3.1416$

" $1\frac{3}{4}''=1\frac{3}{4}^2 \times .7854=2.4053$

Answer, .7363 square inches.

To find the area of an ellipse.

RULE.—*Multiply* .7854 *by the product of the diameters.*

Fig. 8.

EXAMPLE.

What is the area of an ellipse whose diameters are $5\frac{3}{4}$ and $4\frac{1}{3}$? See fig. 8.

5.75	24.4375
4.25	.7854
2875	977500
1150	1221875
2300	1955000
24.4375	1710625
	19.19321250

To find the surface or envelope of a cylinder.

RULE.—*Multiply* 3.1416 *by the diameter, to find the circumference, and then by the height.*

EXAMPLE.

What is the surface of a cylinder whose diameter is 9 inches and height 15 inches? See fig. 14, page 50.

3.1416	
9	
28.2744	circumference
15	
1413720	
282744	
424.1160	area of surface in square inches.

MEASUREMENTS OF SOLIDS.

A *Cube* is a solid having six equal square sides.

To find the contents.

RULE.—*Multiply the area of the base by the perpendicular height.*

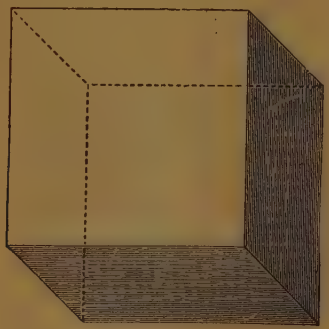


Fig. 9.

EXAMPLE.

What are the contents of a cistern whose sides and depth are 3 feet 6 inches?

Now, 3′ 6″=decimal 3.5 $3.5 \times 3.5 \times 3.50 = 42.875$ nearly 43 cubic feet.

The unit of cubic measure is a cube, each of whose edges is a unit of some known length. Thus, a cubic inch is a cube, each of whose edges is one inch; a cubic foot is a cube, each of whose edges is one foot; etc.

1 cubic foot contains 1728 ($12 \times 12 \times 12$) cubic inches; 1 cubic yard, 27 ($3 \times 3 \times 3$) cubic feet.

The U. S. measurement ton for freight contains 40 cubic feet.

The U. S. register tonnage (entire internal cubical capacity) of vessels is expressed in tons of 100 cubic feet each.

To find the contents of a rectangular solid.

RULE.—*Multiply the length, breadth and height together.*

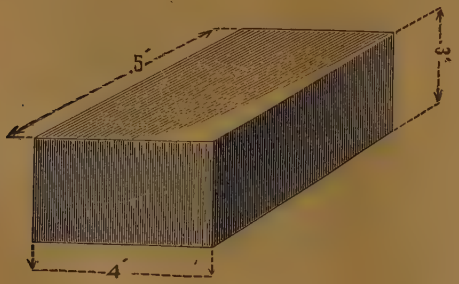


Fig. 10.

EXAMPLE.

What is the contents of a rectangular solid whose length is 5 feet, breadth 4 feet and height 3 feet?

5 feet
4 feet
—
20 square feet of base
3 feet
—
60 cubic feet

To find the cubic contents of a sphere.

RULE.—*Multiply* .7854 *by the cube of the diameter, and then take* $\frac{2}{3}$ *of the product.*

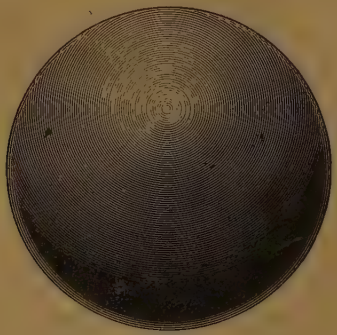


Fig. 11.

EXAMPLE.

Find the cubic contents of a sphere whose diameter is 5 feet.

5	.7854
5	125
25	39270
5	15708
125 = 5^3	7854
	98.1750
	2
	3)196.3500

Answer, 65.4500 cubic feet.

To find the solidity of a cone.

RULE.—*Multiply the area of the base by the perpendicular height, and $\frac{1}{3}$ of the product will be the solidity.*

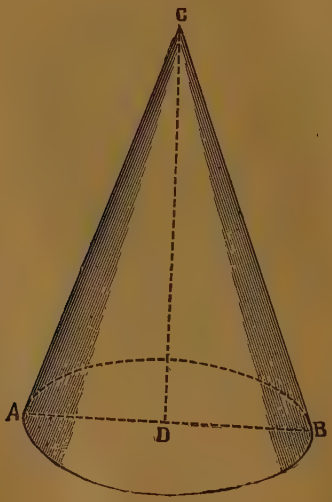


Fig. 12.

EXAMPLE.

1. Required, the solidity of the cone *A B C;* the diameter, *A B*, of the base being 12 feet, and the perpendicular altitude, *D C*, 18 feet 6 inches.

Here $.7854 \times 12^2 = .7854 \times 144 = 113.0976$, the area of the base; and $(113.0976 \times 18.5) \div 3 = 2092.3056 \div 3 = 697.4352$ feet, the solidity required.

To find the solidity of a segment of a sphere.

RULE 1.—*To three times the square of the radius of the segment's base, add the square of the depth or height; then multiply this sum by the depth and the product by* .5236.

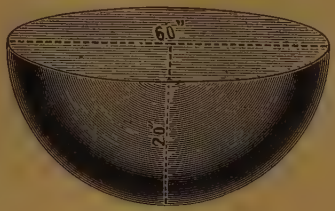


Fig. 13

EX.—How many cubic inches in a spherical segment which has a diameter of 60 inches and a depth of 20 inches?

60÷2=30 inches radius. 30×30×3=2700; 2700+(20×20)=3100; 3100×20×.5236=32463.2, which is the number of cubic inches.

RULE 2.—*From three times the diameter of the sphere subtract twice the height of the segment; multiply the remainder by the square of the height, and that product by* .52361 *for the solidity.*

EX.—If the diameter of a sphere be 3 feet 6 inches, what is the solidity of a segment whose height is 1 foot 3 inches? Ans. 6.545 feet.

Now, 3.5 ×3=10.50 | 1.25×1.25=1.5625×8=12.5
1.25×2= 2.50

8

Then, 12.50×.52361=6.545. Answer.

NOTE.—When the segment is greater than a hemisphere, find the solidity of the lesser segment and subtract the same from the solidity of the entire sphere.

To find the cubic contents of a solid cylinder.

RULE.—*Find the area of the base, and multiply this by the height or length.* (*See Fig. 14, where P represents the diameter and the "l or h" the length or height.*)

Fig. 14.

EXAMPLES.

1. What is the cubic contents of a cylinder whose diameter is 4 feet and height or length $7\frac{1}{2}$ feet?

```
 4          .7854
 4            16
---        ------
16         47124
           7854
           ------
           12.5664=area of base in square feet
              7.5=height or length in feet
           ------
           628320
          879648
          ------
```

Answer, 94.24800 cubic feet.

2. What is the cubic contents of a gallon (U. S.) measure 7 in. in diameter×6 in. deep?

$7\times7=49\times.7854=38.4846$ area.

Now, $38.4846\times6=231$ cubic in. (nearly).

TO REDUCE INCHES TO A DECIMAL OF A FOOT.

RULE.—*Add a cypher to the inches and divide by 12; the quotient is the first decimal; if there is a remainder, add a cypher and divide again and so on.*

EXAMPLES.

Reduce 9 inches to the decimal of a foot.

$$12)900$$

.75 Answer.

Reduce 8 inches to the decimal of a foot.

$$12)8000$$

.666+

CIRCULAR INCHES.

A circular inch is a circle whose diameter is one inch; instead of finding diameters in square inches it is frequently convenient to use the circular inch.

To find the circular inches in a circle.

RULE.—*Square the diameter of the circle in inches, as per the following:*

EXAMPLES.

1. How many circular inches are there in a safety valve whose diameter is $4\frac{1}{2}$ inches?

$4.5^2 = 4.5 \times 4.5 = 20.25$ or $20\frac{1}{4}$ Answer.

2. The diameter of a piston is 50 inches, how many circular inches are there in it?

$50^2 = 2500$

or, $50 \times 50 = 2500$ circular inches. Answer.

MEASUREMENT OF TANKS.

A *tank* is a cistern constructed to hold liquids: they are usually made of iron thinner than boiler plate and thicker than sheet iron.

A *graduated tank* is one fitted with water gauges and indicating marks at different heights, between which the capacity of the tank is known.

A *ship's ballast-tank* is the compartment for water to be pumped in and out for the purpose of insuring the proper stability of the vessel, to avoid capsizing and to secure the greatest effectiveness of the propelling power.

The contents of cisterns and tanks are estimated either in gallons or in cubic feet.

A *gallon* (U. S.) is equal to 231 cubic inches or 0.13368 cubic feet and weighs $8\frac{1}{3}$ lbs. nearly (8.3356 lb. at 62° F). This is almost exactly equivalent to a cylinder 7 inches in diameter and 6 inches in height. See page 50 for calculation.

The imperial gallon of England contains 277.274 cubic inches, and is equivilent to 1.2 U. S. gallons and at 62° Fah. weighs 10 lbs.

A cubic foot contains $7\frac{4805}{10000}$ ($7\frac{1}{2}$ nearly) U. S. gallons.

A barrel=$31\frac{1}{2}$ gallons. 1 hogshead=2 bbls.=63 gallons.

RULE.—*Reduce the measurement of a tank or cistern to cubic feet by multiplying the height, length and breadth together and then reduce to gallons by multiplying by* 7.4805 *or* $7\frac{1}{2}$.

EXAMPLE.

A tank is 7 feet deep, 4 feet wide and $8\frac{1}{2}$ feet long, how many gallons does it hold when $\frac{2}{3}$ full?

7 × 4	7.4805 gallons in
4	238 cubic feet.
28	598440
$8\frac{1}{2}$	224415
14	149610
224	1780.3590 gallons.
238	2
	3) 3560.7180

Answer, 1,187 gallons.

Again. The problem can be worked out by dividing the cubic feet (238) by .13368 which equals one gallon (U. S.)

.13368)238.00000	=	1780.37 cubic feet.
13368		2
104320		3)3560
93576		1187 gallons when $\frac{2}{3}$ full.
107440		
106944		
49600		
40104		
94960		

In working problems relating to tanks the student may profitably refer to the illustrations beginning on page 45 under section relating to the measurements of solids.

COAL BUNKERS.

A coal bunker is a large bin, arranged for the stowage of anthracite or bituminous coal. Calculations relative to them are often of vital importance.

To find the dimensions and capacity of coal bunkers.

RULE.—*Multiply the length, breadth and height together in feet and decimals of a foot. Divide the result by the number of cubic feet per ton of coal; assume in the following example that one ton of coal occupies* 43 *cubic feet of space.*

EXAMPLE.

A coal bunker is 30 feet long, 9 feet high, 8 feet 6 inches in width. How many tons of coal will it hold?

$30 \times 9 \times 8.5 = 2295$ cubic feet.

$$43)2295.(53\tfrac{16}{43}\text{ Tons}$$
$$215$$
$$145$$
$$129$$
$$16$$

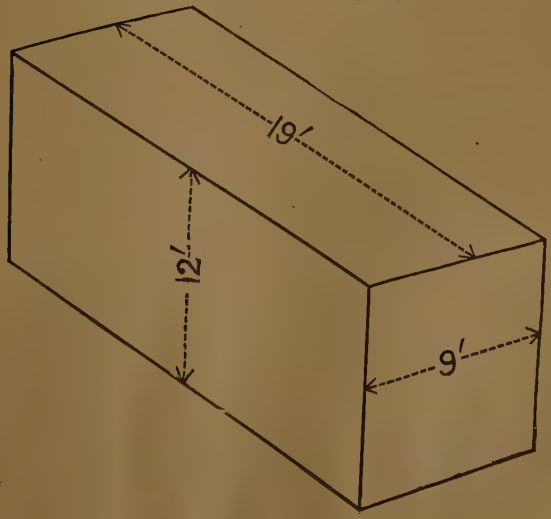
NOTE.—The weight of coal *in the solid lump* is from 70 to 80 pounds per cubic foot for bituminous grades, and from 85 or 90 to 100 pounds per cubic foot for anthracite grades. *When broken up* in ordinary commercial sizes, however, its weight, in bulk, is usually from 50 to 54 pounds per cubic foot for bituminous, and from 53 to 58 pounds per cubic foot for anthracite.

These weights correspond to an allowance of from 42 to 45 cubic feet per ton of 2,240 pounds for bituminous grades and from 39 to 42 cubic feet per ton for anthracite grades. In estimating the capacity of coal bunkers the above figures are usually taken, varied, however, by the size of the lumps of the coal.

In all estimates where a ton is brought in, it is important to remember the difference between a *long* and a *short* ton. The first contains 2,240 lbs. and corresponds to the English ton. In the United States the ton is commonly estimated at 2,000 lbs.

Ex.—What is the capacity of a coal bunker 19 feet long, 9 feet wide, and 12 feet high, with coal requiring 40 cubic feet for each ton of 2,000 pounds?

Fig. 15.



Now, 19
9
171
12

2052 cubic feet, or thus—

$19' \times 9' \times 12' = 2052'$ cubic feet.

Now divide 2052 by $40 = 51\frac{12}{40}$ or 51.3 tons. Ans.

Ex.—What is the area of the end of a bunker in square feet, sloped as in the figure, top-width 18 feet, middle 14 feet, and the bottom dimension 10 feet?

Rule.—*Add together the top dimension, 4 times the middle one, aud once the bottom one, and divide the sum by 6; the result is the mean width; next multiply by the height to get the area in square feet.*

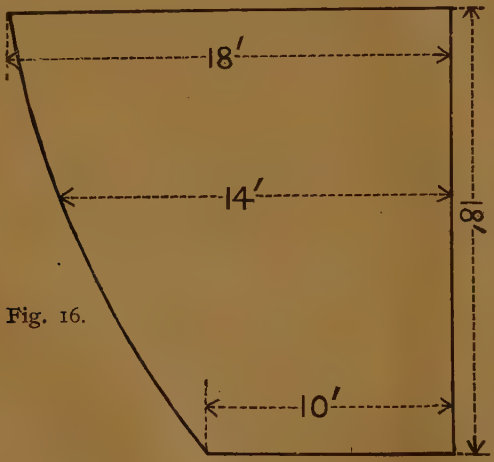


Fig. 16.

Example.

The upper 18
$4 \times 14 = 56$
the lower 10

6) 84

14 = mean width.

Now, $14 \times 18 = 252$, area in square feet.

Assuming the length of the bunker in the last example to be 30 feet, with coal requiring 45 cubic feet for a ton of 2,000 lbs. how many tons will it hold?

Now, $30 \times 252 = 7560$ cubic feet.
Divide 7560 by 45 = 168 tons. Answer.

EXAMPLE.

A cross bunker is 25 feet long, 34 feet wide at the top, 30 feet wide at the bottom and 32 feet wide in the middle, the depth being 12 feet. How many tons of coal will it hold?

Top 34 feet.
Bottom 30
4 times middle 128

6)192(32 mean width.
18

12
12

Now, $25 \times 32 \times 12 = 9600$ cubic feet.

Assume 40 feet to one ton.

40)9600(240 tons
80

160
160

Ex.—What is the area in square feet at the end of a bunker 10 feet at the top, and 6 feet at the bottom, and 18 feet high?

RULE.—*Add together the bottom and top dimensions and divide by 2 in order to obtain the mean width; next, multiply the result by the height to find the area in square feet.*

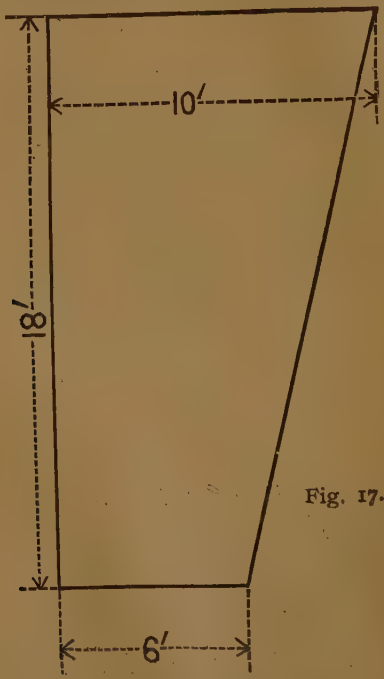


Fig. 17.

Now: $\frac{10+6}{2}=\frac{16}{2}=8$ feet mean width.

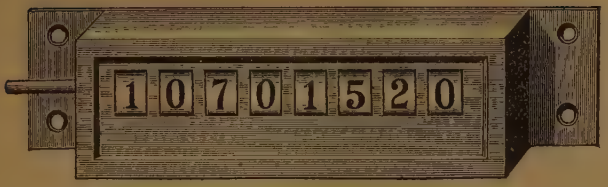
$8' \times 18' = 144$ square feet, and if the bunker is 25 feet long, how many cubic feet does it contain?

$144 \times 25 = 3600$. Answer.

With coal occupying 41 cubic feet to the ton of 2000 pounds, what is its capacity?

$3600 \div 41 = 87\frac{33}{41}$ tons. Answer.

Fig. 18.



SPEED PROBLEMS.

The accompanying figure represents an engine-counter, a device which records by wheel combinations the revolutions of an engine or machine where it is necessary or convenient to know the number of rotary turns within a specified time. Whatever number of dials or wheels there may be, the right hand figure represents *the units*, the second figure *the tens*, etc. In the illustration the numbers read ten million seven hundred and one thousand five hundred and twenty.

After recording 99.999.999 the eight dials automatically change to the figures 00.000.000, thus making an endless round. It is necessary in very long voyages or with an engine-counter having few dials to keep record of *the complete revolutions the device has made.*

This ingenious mechanism is capable of various applications relating not only to the number of revolutions the engine has made, but telling how many miles a steamer has gone, and also what has been the consumption of coal and the speed per day, etc. These calculations must take reckoning of "the slip" of the propellers.

NOTE.—For measuring the speed of steamships the customary unit is *the knot;* while this term is often used as a distance it is really *a speed or velocity*, each division of the log line serving to measure the rate of the ship's motion. Each knot on the line bears the same proportion to a mile that thirty seconds do to an hour; the number of knots which run off from the reel in half a minute, therefore, shows the number of miles the vessel sails in an hour. As adopted by the U. S., a knot is a speed of $6080\frac{27}{100}$ feet per hour; the British knot is a speed of 6080 feet per hour.

PROBLEMS RELATING TO HORSE POWER.

There are three kinds of horse power spoken and written about which engineers should learn to distinguish—these are:

1. *Nominal,*

2. *Indicated*, and

3. *Effective.*

Engineers and others who have not carefully considered the matter, often use the above as having the same meaning; but the meaning is far from the same.

Nominal horse power is an expression which is gradually going out of use, and is merely a convenient mode of describing the *dimensions* of a steam engine for convenience of makers and purchasers of steam engines.

Indicated horse power is the true measure of the work done within the cylinder of the steam engine and is based upon no assumptions, but is actually calculated.

Effective horse power is the amount of work which an engine is capable of performing, and is the difference between the indicated horse power and horse power required to drive the engine when it is running unloaded.

As defined in answer to question 15, horse power is a measure of power equal to 550 foot-pounds per second, or 33,000 foot-pounds per minute, or in other words 33,000 pounds lifted one foot in one minute, or one pound lifted 33,000 feet in one minute.

The capacity for work of the steam engine is expressed in the number of horse-powers it is capable of developing.

The calculations relating to the horse-power produced under different conditions are of the utmost importance; the horse-

power of any engine whether condensing or non-condensing, single, double or compound, is found by one and the same—

RULE.—*Multiply the area of the piston in square inches by the mean (or average) effective steam pressure in pounds on the piston, 2; and this by the space in feet traveled through by the piston per minute, 3; and divide this product by 33,000; the quotient is the horse-power of the engine.*

EXPLANATION.

In all rules for estimating the power of different forms of the steam engine, the things necessary to be known in order to correctly make the figures are as follows:

1. The diameter of the cylinder in inches.

2. Length of stroke in feet.

3. The number of revolutions per minute.

4. The mean effective pressure—that is, *the average pressure* of the steam on the piston during the full length of the stroke; and

The latter, 4, is the doubtful part of the calculation; the reasons for this are various, such as the varied expansion, wire-drawing, steam working against itself in the cylinder, condensation, cramping of the exhaust, etc. These defects, as well as the average pressure of the steam (and the combined pressure of the steam and the vacuum) are clearly shown by the Indicator; in the important note page 63 the average pressure is given as calculated by the use of tables, taking into account the ratio of expansion of steam, the percentage of clearance, etc.

EXAMPLE.

What is the horse-power of an engine with cylinde 14″×20″; 50 lbs. average pressure on the piston; speed 16 strokes per minute?

Now, 14″ diam. of piston (per table, or) multiplied by .7854= 154 square inches (nearly) and the forward and backward strok of the piston in one revolution, equals 20×2=40 in.=$3\frac{1}{3}$ feet.

154 square in.=area of piston.
50=pressure of steam.

7700

Again, 160=strokes per minute.
$3\frac{1}{3}$=feet traveled by piston.

$53\frac{1}{3}$
480

$533\frac{1}{3}$ or 533.33

Next multiply the two products together and divide b 33,000 for horse-power.

7700
$533\frac{1}{3}$

2566
23100
23100
38500

4106666

33000)4106666($124\frac{14}{33}$ Answer
33

80
66

146
132

14

The method of finding the mean average pressure by t indicator is to be found in the answers in sections 679 to 7 the student is referred to them as worthy of the most care and attentive study.

Without the aid of an indicator the boiler pressure is substituted for the mean effective pressure as calculated from the diagram; deduct from result obtained from 40 to 60 per cent. for loss by condensation and friction of steam pipes and passages, decrease of pressure in cylinder due to expansion, back pressure of exhaust and friction of the working parts.

To calculate the horse-power by use of the table given in the note below.

EXAMPLE.

The boiler pressure with engine cutting off at half-stroke being 50 lbs., then, multiply 50 lbs. boiler pressure by .847 per table, in decimals.

350
200
400

42.350=43⅓ lbs. mean average pressure on the piston.

Thus, in the example given, page 62, of the 14×20 cylinder when the pressure is given as 50 lbs., provided the engine "cuts off" at ½ stroke the 50 can be changed to 43⅓ to get a more correct answer.

But it must be remembered that even with the table given in the note that the result is only approximate.

NOTE.—The mean pressure in the cylinder when cutting off at

¼	stroke	equals	boiler	pressure	multiplied	by	.597
⅓	"	"	"	"	"	"	.670
⅜	"	"	"	"	"	"	.743
½	"	"	"	"	"	"	.847
⅝	"	"	"	"	"	"	.919
⅔	"	"	"	"	"	"	.937
¾	"	"	"	"	"	"	.966
⅞	"	"	"	"	"	"	.992

FINDING THE MEAN EFFECTIVE PRESSURE FROM AN INDICATOR DIAGRAM.

There are several ways of computing this; the common method is by the use of "ordinates." The meaning of this word is "even spaces or divisions;" in other words, the card is divided, in lines a given distance apart, into a number of even spaces; the diagram or plate page 67 shows two examples of solving the problem by the use of "ordinates."

As is well known, the indicator card shows the pressure exerted on the piston during the entire length of the stroke by dividing the card into, say, ten spaces, and adding the combined pressure at these ten points, an average for the whole stroke may be found by dividing the sum total by ten the mean average pressure.

For ease in making this division, ten spaces are generally used and are enough for practical use, though, of course, the finer the diagram is divided up, the more accurate the computation. But if extreme accuracy is required a planimeter should be used as illustrated and explained on Page 518.

The easiest way in which to divide a card into ten equal spaces is a matter of opinion. Some place a rule diagonally across the card and point off the spaces as shown, see Question 685; others use a rule placed at the bottom of the card as shown in the illustration, page 67, and mark off the spaces with short guiding lines.

After the guiding lines are marked off, ascertain the amount of pressure exerted at a point in the center of each space by measuring the distance from the bottom to the top

line. This may be done in many ways, but as every indicator outfit to-day is equipped with scales, or should be, the use of a scale in measuring the pressure as shown by the height of the card, is the general practice; this may be expressed by the following—

RULE.

Take a scale corresponding with the spring used in the indicator, and measure the distance from the bottom line of the card to the top in the center of each space. In other words, if a 50 scale is used, the card would show 50 pounds for every inch in height from the bottom to the top lines of the card. If a 40 scale, then it would be forty pounds for every inch in height, and the scale, being divided into fortieths, the number of pounds pressure is easily seen by counting the divisions on the scale.

The pressure as found by the scale in each space should be added together (see plate) and the sum divided by the number of spaces used, which will give the mean effective pressure of the card.

Another method frequently used is to take a strip of paper and measure the height of each ordinate consecutively, which will give the number of inches pressure shown in all the ordinates, then multiplying the results by the number of spring used, and dividing by the number of ordinates, the mean effective pressure is given in pounds. For instance, in Example 1 the combined measurements of the ordinates in inches would be 8.15 inches, this multiplied by the number of spring used (40) would give 326, which divided by 10, would give 32.6 lbs. mean effective pressure.

Examples Worked Out.

An easy way to divide by ten is to point off one figure and leave the M. E. P. in decimal form, it being much easier to use in computing the horse-power. (See plate, p. 67.)

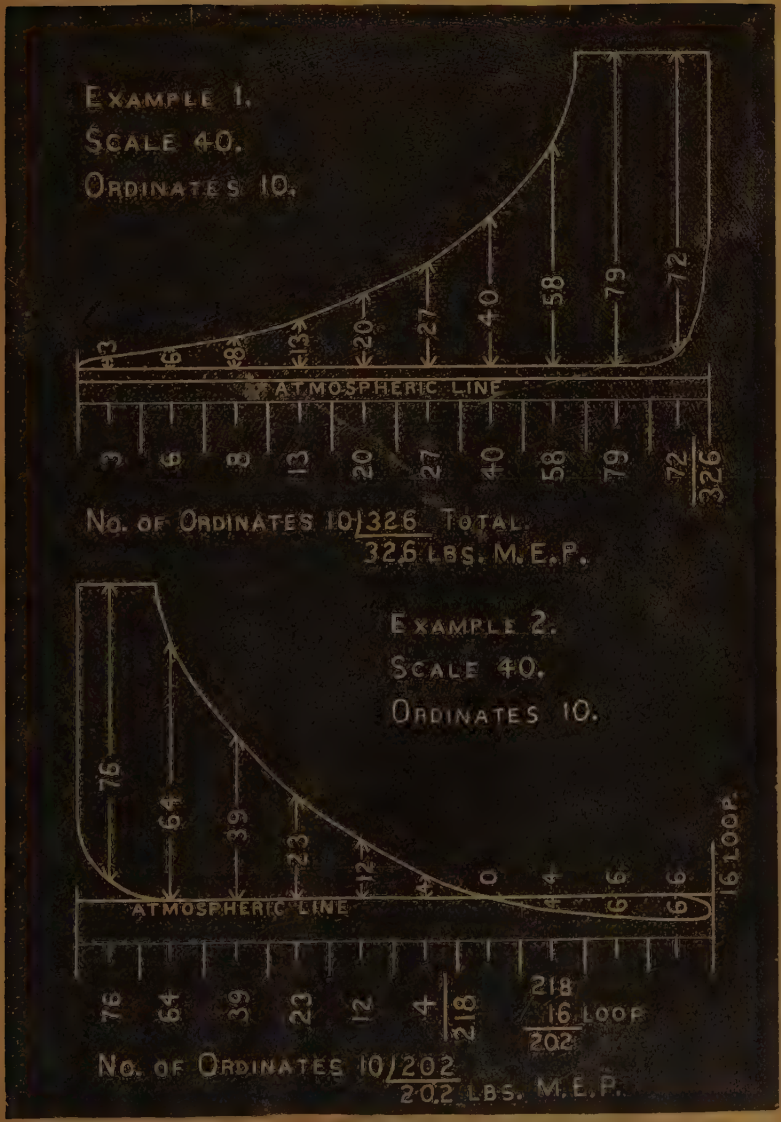
In example 1, the total pressure found by adding all the measurements, making 326 pounds, this divided by ten, the number of ordinates, gives 32.6, which is the mean effective pressure.

When a card from a non-condensing engine shows a loop below the atmospheric line (see example 2), it indicates that all pressure shown in such a loop is a loss, or negative pressure, and the sum of all pressures found in the ordinates in such space should be deducted from the sum of these in positive space, as the mean effective pressure has been lessened by the force required to overcome the resistance shown by the loop.

In example 2 the total pressure found in the positive space ordinates is 218. Subtracting from this the 16 found in the negative space below the line, we have 202 for the total number of ordinates. Dividing this by 10, the number of ordinates, we have as a result 20.2 lbs. mean effective pressure.

HORSE-POWER OF COMPOUND ENGINES.

Compound engines are those which have two or more cylinders of successively increasing diameters so arranged that the exhaust steam from the first and smallest cylinder is passed forward to do work in a second cylinder before escaping to the condenser. To calculate the horse-power of these *proceed by the same rule applied to each cylinder; adding the totals together gives the power of the whole.*


EXAMPLE 1.
SCALE 40.
ORDINATES 10.
3
6
8
13
20
27
40
58
79
72
ATMOSPHERIC LINE
3 6 8 13 20 27 40 58 79 72
326
NO. OF ORDINATES 10/326 TOTAL.
326 LBS. M.E.P.
EXAMPLE 2.
SCALE 40.
ORDINATES 10.
76
64
39
23
12
4
0
4
6
6
16 LOOP.
ATMOSPHERIC LINE
76 64 39 23 12 4 218
218
16 LOOP
202
NO. OF ORDINATES 10/202
20.2 LBS. M.E.P.

19, 20.

EXAMPLE.

What is the H. P. of a compound engine whose high pressure cylinder is 16 inches in diameter, and low pressure 27 inches, with 16 inch stroke, and 250 revolutions per minute? Estimate the mean effective pressure as 70 lbs. for the 16 inch cylinder and 12 lbs. for the 27 inch cylinder. Now:

16″ area=201	27″ area=572.5 inches.
70	pressure 12 lbs.
14070	6870.0
feet traverse 666	feet traverse 666
84420	41220
84420	41220
84420	41220
33,000)9370620(284 nearly.	33,000)4575420(139 nearly.

Add 284 high pressure cylinder, non-condensing.
139 low " " "
423 total (nearly).

HORSE POWER OF DOUBLE ENGINES.

The horse-power of *double engines*, such as locomotives and hoisting engines, is found by multiplying the power obtained from the data relating to one side by 2, in order to obtain the horse-power of both sides or the engine as a whole.

HORSE-POWER OF TRIPLE AND QUADRUPLE EXPANSION ENGINES.

These are best worked out according to the rules for finding each cylinder separately and then by adding the several sums together.

FORMULA FOR INDICATED HORSE-POWER.

$$\text{Indicated horse-power} = \frac{\text{PLAN}}{33.000}$$

Where P=mean effective pressure on piston in pounds per square inch.

A=Area of piston in square inches.

N=Number of strokes per minute.

L=Stroke in feet.

The student is referred to page 37 for instruction as to the solving of formulas.

TO FIND THE HORSE-POWER BY MULTIPLYING.

Instead of putting down the work in solving the problems step by step, they may be more readily solved as follows: *Square the diameter of the piston* in inches, multiply it by the *length of Stroke in feet by twice the revolutions in feet, by the pressure per square foot and by* .0000238. The figures named are *constant multipliers* formed by dividing .7854 by 33.000.

EXAMPLE.

What is the horse-power of an engine, the diameter of cylinder being 13 inches, length of stroke 12 inches, revolutions per minute 300, and the average pressure per square inch on the piston 67 lbs.?

```
      13 diameter in inches.
      13
     ---
      39
     13
    ----
     169
       1  length of stroke in feet.
    ----
     169
     600 twice the revolutions.
   ------
  101400
      67 lbs. pressure per square inch.
   ------
  709800
 608400
 -------
 6793800
 0000238 constant multiplier.
 --------
 54350400
  203814
  135876
 ---------
 161.6924400 horse-power or, 161 7/10 H. P.
```

NOTE.—Entire accuracy in estimating the horse-power of engines requires allowance for the area of the piston rod, which, however, effects one stroke only of the two. The area of the piston rod may be deducted from the area of the piston on one stroke or one-half the area on the two.

THE LEVER.

The lever is usually named as the first of the six mechanical powers and is of three kinds, according as, (1) *the fulcrum* (or prop), (2) *the weight*, or (3) *the power*, respectively, is situated between the other two.

A fulcrum is a prop or support; it is the part by which a lever is sustained or about which it turns in lifting or moving a body; in the illustrations the fulcrum is indicated by F.

It is with the lever of the third class that the Engineer needs to be familiar in calculations relating to the safety valve.

Section 5 of rule 5 United States Boiler Inspection and Engineers' License Laws provides that "no person shall receive a license (as an engineer) who is not able to determine the weight necessary to be placed on the lever of the safety valve (the diameter of the valve, length of lever and distance of valve from fulcrum being given) to withstand any given pressure of steam in a boiler, or who is not able to figure and determine the strain brought on the braces of a boiler with a given pressure of steam, the position and distance apart of braces being known; such knowledge to be determined by an examination in writing, and the report of examination filed with the application, in the office of the local inspectors, and no engineer or assistant engineer, now holding a license, shall have the grade of the same raised without possessing the above qualifications."

THE EXAMINATION OF ENGINEERS.

From the above quotation, and because questions upon the safety valve are so often asked in the examination of engineers desiring a new license or increased grade, that the importance of the subject to the aspiring student is most apparent.

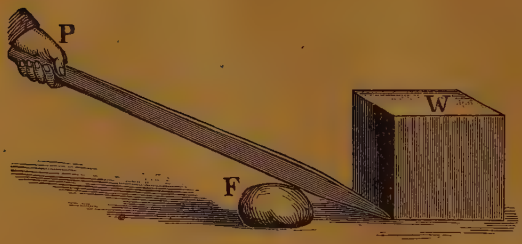


Fig. 21. Lever first kind.

When the *fulcrum* (*F*) is placed between *the force* (*P*) and *the weight* (*W*), the lever is said to be one of *the first class*. See fig. 21.

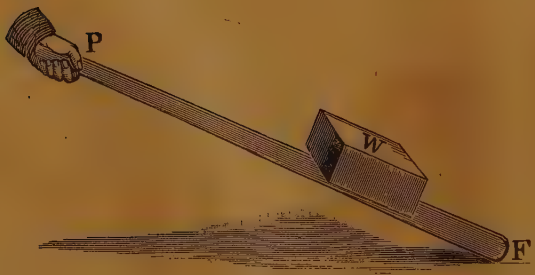


Fig. 22. Lever second kind.

When the *fulcrum* (*F*) is placed at one end of the lever, *the force* (*P*) at the other, and *the weight* (*W*) between them, the lever is said to be of *the second class*. See fig. 22.

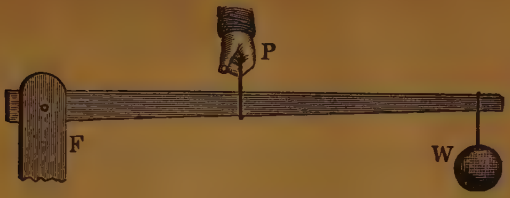


Fig. 23. Lever third kind.

In a lever of the third class the *force* (P) is on the middle, with the *weight* (W) at one end, and the *fulcrum* (F) at the other. See fig. 23.

One important feature should be noted, that in all cases *the lever arms should be measured from the fulcrum;* if this is remembered the liability of making mistakes will be lessened.

A straight line drawn from the fulcrum (F) perpendicular to the line of action of the force (P), is called *the lever arm of the force.*

A straight line drawn from the fulcrum (F) perpendicular to the line of action of the weight (W), is called the *lever arm of the weight.*

If the arms form one straight line, the lever is called *a straight lever;* if the actual arms do not form a straight line, the lever is called "*a bent lever.*"

The centre of gravity is any point where the lever would be balanced, if balanced over a knife edge.

NOTE.—The total upward steam pressure on the valve is found by multiplying the area of the valve in square inches by the steam pressure in pounds. In the above figure the P may be supposed to stand for the steam pressure.

CALCULATIONS RELATING TO THE LEVER.

When two forces act on each other by means of any machine, that which gives it motion is called *the power*, that which receives it *the weight*, hence the use of letters P, W, and F in the

General Rule.

The force (*P*) *multiplied by its distance from the fulcrum* (*F*) *is equal to the weight* (*W*) *multiplied by its distance from the fulcrum.*

In the following examples the distances are figured in inches and the weight in pounds, the *unit of distance* being one inch, and the *unit of weight* being one pound.

Example.

If a force of 80 lbs. be applied at the extreme end of a 5 foot lever (with prop 1 foot from the point), what weight is needed to balance the 80 lbs. The two leverages being 48 inches and 12 inches.

Now, multiply the force (P) 80 lbs., by the distance from the fulcrum (F) 48 inches and divide by 12 inches.

48
80
---
12)3840
320 lbs.

Proof.
48×80 lbs.=3840
12×320 " =3840

This is an example of the General Rule worked from the lever of the first kind. See fig. 21.

From the general rule may be deduced the following useful sub-rules, which will cover all problems where three only of the numbers are known.

To find the power.

RULE.—*Multiply the weight by its distance from the fulcrum, and divide by the distance of the power from the fulcrum. The quotient is the power.*

EXAMPLE.

How much to balance 200 lbs. (W), 18 inches from the fulcrum (F). The whole length of the lever being 36 inches. See fig. 22.

18 in.
200 lbs.

36 in.)3600(100 lbs. Answer.

PROOF.
200 × 18 = 3600
36 × 100 = 3600

To find the weight.

RULE.—*Multiply the power by its distance from the fulcrum, and divide by the distance of the weight from the fulcrum. The quotient is the weight.*

EXAMPLE.

If 480 lbs. be applied at the end of a lever, 135 inches from the fulcrum, what weight will it lift 45 inches distant from the fulcrum. See fig. 22.

480 × 135 = 64800
Divide 64800 by 45
= 1440 lbs. Ans.

PROOF.
1440 × 45 = 64800
480 × 135 = 64800

To find the distance of the power from the fulcrum, the weight and its distance, and the power being given.

RULE.—*Multiply the weight by its distance from the fulcrum and divide by the power.*

EXAMPLE.

If a weight 900 lbs. be 12 inches from the fulcrum, at what distance must a power of 80 lbs. be applied to balance it? See fig. 21.

12
900

80)10800(135 inches. Ans.
80

280
240

400

PROOF.
900×12=10800
135×80=10800

To find the distance of the weight from the fulcrum.

RULE.—*Multiply the power by its distance from the fulcrum, and divide by the weight.*

EXAMPLE.

If the power be 1,000 lbs., 3 inches from the fulcrum, at what distance must the weight (W) 120 lbs. be placed to balance it. See fig. 23.

1000 lbs. power.
3 in. distance.

120)3000
25 inches.

PROOF.
1000× 3=3000
120×25=3000

Ans. 25 inches from the fulcrum.

EXPLANATION.

These calculations relating to the lever are made on the supposition that the action of the mechanical powers is not impeded by their own weight, or by friction and resistance.

The examples not only illustrate the rule, but what may be called the principles of the lever; any one who has used a bar knows it makes a difference how long a "bite" he takes, how he places the block upon which the lever pries, and where he takes hold of the lever, thus a crowbar is an excellent example of the principle of the lever.

Or in other words, when a weight or any force acts upon one part of a lever, its effect upon any other part of the lever can be found by first multiplying the weight by its distance from the fulcrum and then dividing the result by the distance of the other point from the fulcrum.

If the weight of the lever is included in such calculations its influence is the same as if its whole weight or its mass were collected at its center of gravity.

These pages relating to the lever, it will be seen by the acute student, are mainly preliminary to the subject-matter of the larger and more important calculations relating to the safety-valve, beginning at the following page.

FOOT-POUNDS AND INCH-POUNDS.

A foot-pound is a unit of work representing the work done in raising one pound avoirdupois against the force of gravity the height of one foot.

Inch-pound. This is a unit of energy, being the work done in raising a pound through an inch; its value varies in different localities, being dependent on gravity.

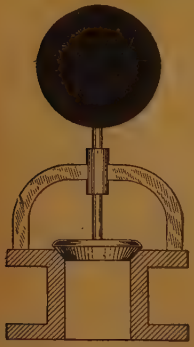
THE SAFETY VALVE

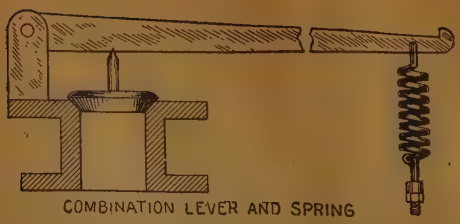
What is the most important valve on any type of boiler?

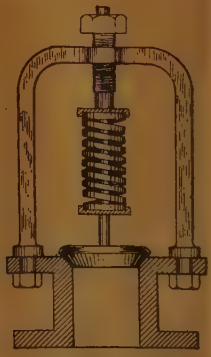
The safety valve.

What is the object of the safety valve?

To prevent the steam rising above the safe working pressure or above the pressure at which it is set.







FIGS. 24 to 27.—Elementary safety valves showing various types. Fig. 24, dead weight valve; fig. 25, lever valve; fig. 26, combination lever and spring valve; fig. 27, spring valve.

What care should a safety valve receive?

It should be kept clean and should be raised by hand every morning.

Why should it be raised so often?

So that it cannot stick in its seat through the accumulation of dirt and scale.

What types of safety valve are in general use?

The lever safety valve, and the spring safety valve.

There are two other types: 1, the dead weight valve used sometimes for very low pressure apparatus as in steam heating; and 2, the combination lever and spring valve in which a spring is used in place of the weight on a lever valve. This type is used principally in England. The four types just mentioned are shown in figs. 24 to 27.

For what service is each intended?

The lever valve is used principally in stationary practice and sometimes on ferry boats, side wheel steamers and other craft navigating quiet waters and carrying moderate or low pressure steam.

How should a safety valve be attached to the boiler?

It should be attached to a separate outlet, but if only one outlet be on the boiler it may be attached to a tee on main steam pipe, as close to the boiler as possible without any kind of valve between it and the boiler.

What features should a good safety valve possess?

A good safety valve should be: 1, large enough in diameter, and have sufficient *lift* to allow the steam to escape as fast as it is generated, when the pressure is slightly above that to which it is set; 2, it should close as soon as the pressure has dropped a predetermined amount below the set pressure; 3, it should be enclosed or so protected that it cannot be tampered with or accidentally interfered with by contact with foreign objects; 4, for marine purposes it must be so constructed as not to be affected by the motion of the boat.

What defects occur in safety valves, and how are they repaired?

The valve may be broken, which fact will be shown by steam escaping through the escape pipe. Nothing can be done until it is all gone. In case the valve itself, or the spindle, be broken, sometimes a new valve can be built by fitting a disc of heavy plate into which a stem is riveted in the center.

If the spring give out and no spare one be on hand, it may be possible to fit a long lever, pressing on the spindle of the valve and load it at the end with

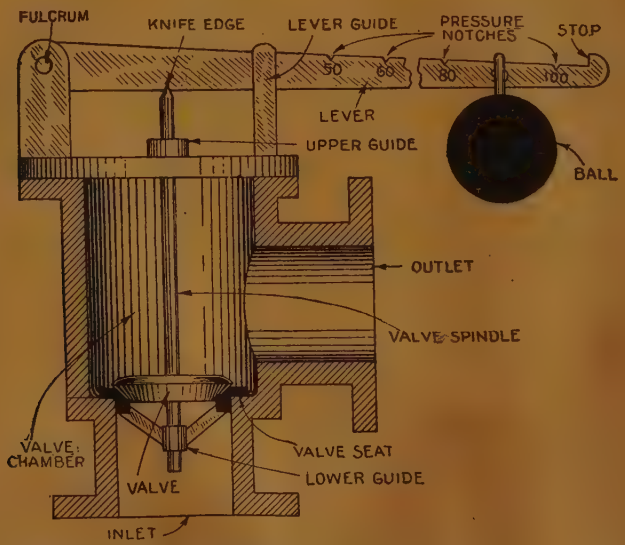


FIG. 28.—Sectional view of a lever safety valve showing essential parts.

sufficient weight to hold the normal pressure. Where room permits, lead discs may be cast and placed on the spindle and the valve thus loaded.

In case the valve be jammed and do not blow off with a rapidly rising steam pressure, the valve may be given a sharp blow, which sometimes will start it. If this do not produce the desired relief, all steam outlets to auxiliaries and condenser must be turned on full, to work off the steam. Fire and uptake doors are better opened and the fires deadened with wet ashes, until well within the working pressure.

The steam is better allowed to fall until it is possible to dismount the valve and refit it in efficient condition.

THE LEVER SAFETY VALVE

Construction.—The essential parts of a lever valve consist of

1. A valve chamber containing the valve seat, inlet and outlet opening;

2. A cover containing the upper spindle and lever guides, also an arm having a pivot hole at its end forming the *fulcrum;*

3. A *valve* and *spindle*, the latter being attached to the valve and the projecting part terminating in a *knife edge;*

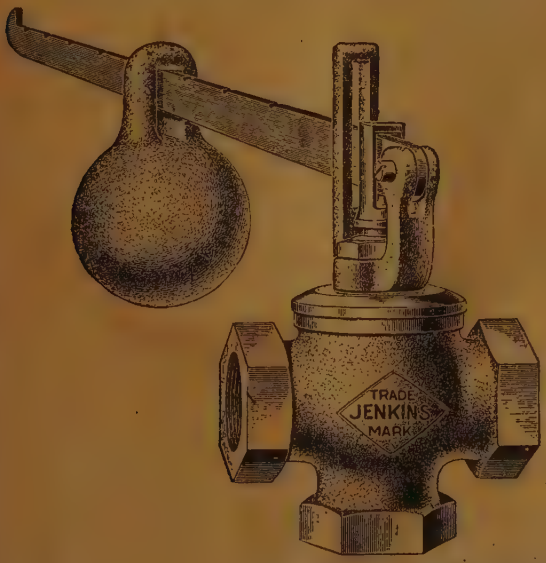


FIG. 29.—View showing actual construction of lever safety valves, T type.

4. A *lever*, pivoted at one end to the projecting arm or *fulcrum*, in contact with the knife edge of the spindle at an intermediate point and weighted at the other end with a *ball.*

The actual construction of lever valves is shown in the accompanying cuts.

Why is a lever valve objectionable on vessels navigating rough water?

The inertia of the weight produces a variable pressure on the valve tending to close and open the valve respectively with rise and fall of the boat on the waves. Moreover, when the boat rocks, the horizontal position of the lever is disturbed and the blowing pressure of the valve is lowered.

How is the pressure regulated on the lever safety valve?

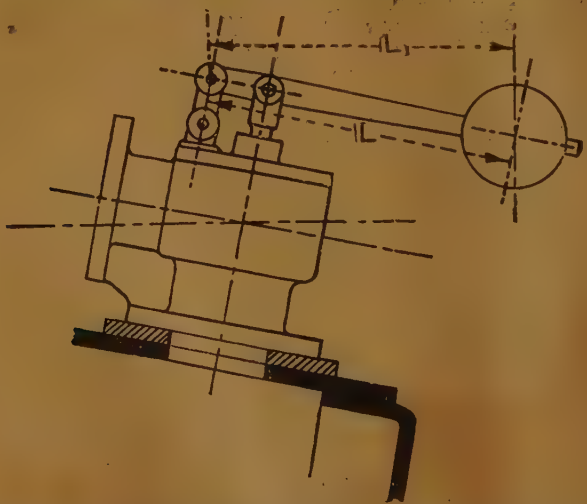


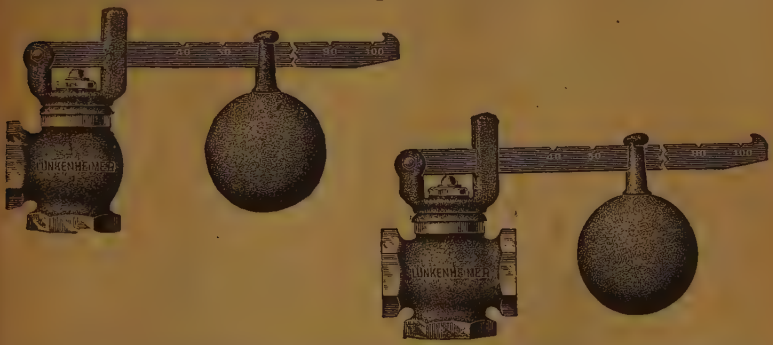
FIG. 30.—Diagram of a lever safety valve, showing decrease of the weight's effect, as the result of incline in a heavy sea. In the diagram, L, is the length of the lever arm, the full length being effective when horizontal but when inclined the effective length is reduced to L_1

By moving the weight on lever; the farther it is from valve the greater the blowing off pressure.

RULE II, 23.—All common lever safety valves to be hereafter applied to the boilers of steam vessels shall be constructed in material, workmanship, and principle according to the requirements for a safety valve referred to in this section. When this construction of a safety valve is applied to the boilers of steamers navigating rough waters, the link may be connected direct with the spindle of the valve: *Provided, always*, That the fulcrum or points upon which the lever rests are made of steel, knife, or sharp edged, and hardened; in this case the short end of the lever shall be attached directly to the valve casing. In all cases the link requires but a slight movement not exceeding one-eighth of an inch.

What precaution should be taken with a lever valve?

The lever should be raised **frequently** *permitting the valve to blow to guard against the valve sticking to the seat.*



FIGS. 30*a* and 30*b*.—Lunkenheimer lever safety valves with screw ends. Fig. 30*a* angle valve; fig. 30*b* cross valve. The cross type valve may be used with the bottom and one side as inlets, and the remaining side as outlet.

U. S. REQUIREMENTS IN CONSTRUCTION OF LEVER SAFETY VALVES.

All the points of bearing on lever shall be in the same plane.

The distance of the fulcrum shall in no case be less than the diameter of the valve opening.

The length of the lever shall not exceed the distance of the fulcrum multiplied by ten.

The width of the bearings of the fulcrum shall be not less than three-fourths of 1 inch.

The length of the fulcrum link shall be not less than 4 inches.

The lever and fulcrum link shall be made of wrought iron or steel and the knife edged fulcrum points and bearings for the points shall be made of steel and hardened. But the chambers and saddle flanges of this and all other types of safety valves attached to boilers may be made of cast iron or other suitable material.

The valve, valve seat, and bushing for the stem or spindle shall be made of composition (gun metal) when the valve is intended to be attached to a boiler using salt water; but when the valve is to be attached to a boiler using fresh water and generating steam of a high pressure the parts named, with the exception of the bushings for the spindle, may be made of cast iron. On safety valves constructed after June 30, 1905, neither the valve nor the valve seats shall be of cast iron.

The valve shall be guided by its spindle, both above and below the ground seat and above the lever, through supports either made of composition (gun metal) or bushed with it.

The spindle shall fit loosely in the bearings or supports.

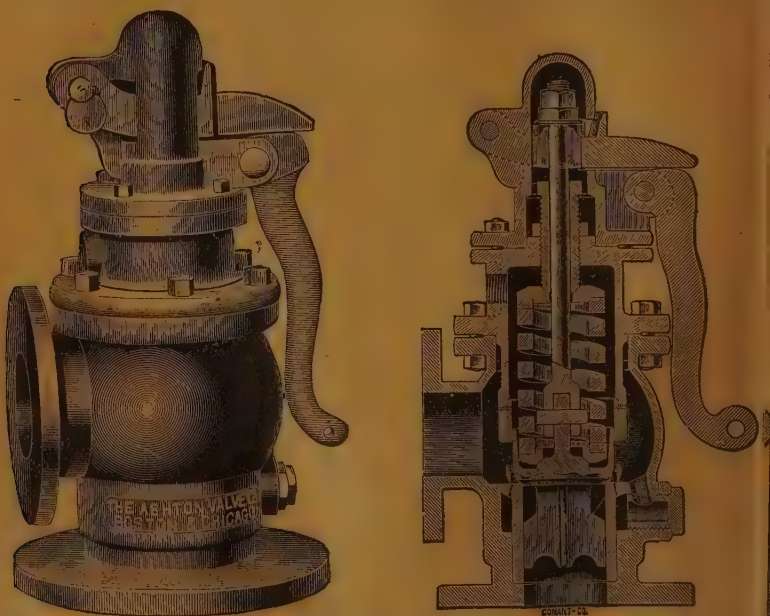
When the valve is intended to be applied to the boilers of steamers navigating rough waters, the fulcrum link may be connected directly with the spindle of the valve; *providing always* that the knife edged fulcrum points are made of steel and hardened, and that the vertical movement of the valve is unobstructed by any lateral movement.

In all cases the weight shall be adjusted on the lever to the pressure of steam allowed in each case by a correct steam gauge attached to the boiler. The weight shall then be securely fastened in its position and the lever marked for the purpose of facilitating the replacing of the weight should it be necessary to remove the same, and in no case shall a line or any other device be attached to the lever or weight except in such a manner as will enable the engineer to raise the valve from its seat. (Sec. 4418, R. S.)

THE SPRING SAFETY VALVE

Construction.—In this type of valve, the force due to the compression of a spring is used to oppose the steam pressure instead of a weighted lever.

The spring, as shown in figs. 30*f* and 30*g* is attached to the lower part of the valve spindle and may be placed inside or outside of the valve chamber.



FIGS. 30*c* and 30*d*.—Exterior and sectional views of Ashton spring pop safety valve. A sprir of known strength, whose tension is adjustable to desired pressure, holds the valve upon i seat. By the lever attached to the valve stem, however, the valve may be raised, allowin the steam to blow off, whenever desired.

The upper end of the spring bears against a cup attached to an adjustab bushing by means of which the pressure on the valve is regulated.

The curved lever arm acting at the top of the spindle is for the purpose operating the valve occasionally by hand to guard against it "sticking," an

thus permitting the pressure to rise above the pre-determined value. The accompanying cuts show actual construction of some modern spring valves.

Why does a pop safety valve "pop"?

In this type of spring valve, the construction is such that as soon as the valve begins to open, an excess area of the disc is presented to the escaping steam, hence it suddenly opens wide.

RULE II, 23.—Any spring loaded safety valve constructed so as to give an increased lift by the operation of steam after being raised from its seat, or any spring loaded safety valve constructed in any other manner, so as to give an effective area equal to that of the aforementioned spring loaded safety valve, may be used in lieu of the common lever weighted valve on all boilers on steam vessels, and each spring loaded valve shall be supplied with a lever that will raise the valve from its seat a distance of not less than that equal to one-eighth of the diameter of the valve opening; but in no case shall any spring loaded safety valve be used in lieu of the lever weighted safety valve without first having been approved by the Board of Supervising Inspectors.

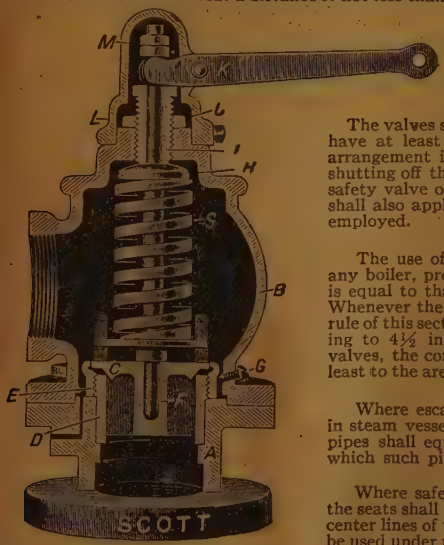


FIG. 30*e*.—Scott spring pop safety valve. ***The parts are:*** A, base; B, iron case; C, bronze valve or disc; D, bronze bushing or seat; E, adjustable ring; F, steel stem and spindle; G, screw to hold adjustable ring; H, spring plate; I, bronze loading bolt; J, lock nut; K, lever (malleable iron); L, iron cap and screw to hold cap; M, stem or lifting nuts.

The valves shall be so arranged that each boiler shall have at least one separate safety valve, unless the arrangement is such as to preclude the possibility of shutting off the communication of any boiler with the safety valve or valves employed. This arrangement shall also apply to lockup safety valves when they are employed.

The use of two safety valves may be allowed on any boiler, provided the combined area of such valves is equal to that required by rule for one such valve. Whenever the area of a safety valve, as found by the rule of this section, will be greater than that corresponding to 4½ inches in diameter, two or more safety valves, the combined area of which shall be equal at least to the area required, shall be used.

Where escape pipes for safety valves are installed in steam vessels after July 1, 1910, the area of such pipes shall equal the combined area of all valves to which such pipes are connected.

Where safety valves are used with beveled seats, the seats shall have an angle of inclination of 45° to the center lines of their axes. Flat seat safety valves may be used under the formula and table under the heading "Safety valves" in Rule II.

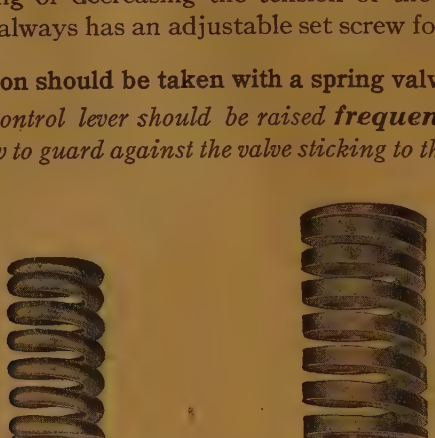
Hereafter no safety valves having a set screw arrangement on top of the valve casing, designed to hold the valve down while the hydrostatic pressure is being applied, shall be allowed. On such valves now in use, inspectors shall require the set screws to be taken out and the hole permanently closed. This does not apply to any safety valve whose form of construction is such that the hole for the set screw or bolt is securely closed when the valve is locked.

How is the blowing off pressure regulated on a spring loaded valve?

By increasing or decreasing the tension of the spring. This style of valve always has an adjustable set screw for this purpose.

What precaution should be taken with a spring valve?

The hand control lever should be raised ***frequently*** *permitting the valve to blow to guard against the valve sticking to the seat.*



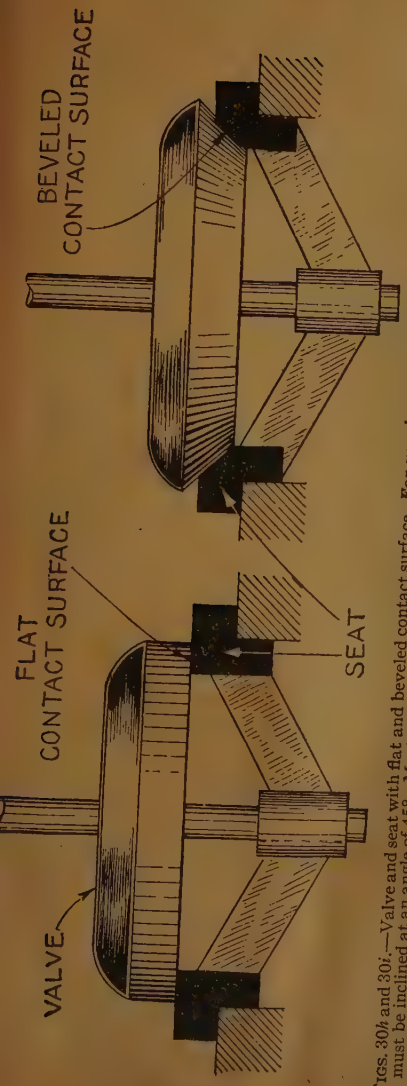
FIGS. 30*f* and 30*g*.—American springs for brass and iron pop safety valves. Fig. 32*f*, round type for brass valves 2 ins. and under; fig. 32*g*, rectangular type for brass and iron valves 2½ ins. and over.

What kind of a spring valve should be used with super-heated steam?

One with an *outside* spring.

NOTE—***Comparison of lever and spring safety valves.*** The lever valve has no definite "pop" point, the valve lifting slowly in opening, and settling gradually in closing. A comparatively long range of blowing is necessary for the valve to effectively open, and a considerable excess pressure is necessary in specifications for such valves. ***Spring valves,*** have a positive opening to practically the full amount. ***At the popping point,*** a properly designed spring valve will lift its maximum, say .15 ins. and this lift will decrease approximately .01 in. per lb that the pressure in the boiler falls below the popping point. Other pressures may force the lift slightly higher with such a valve, but not sufficiently to make these pressures necessary to obtain the full valve efficiency. In specifying spring valves, therefore, an excess pressure should not be allowed, at least not over 1 or 2 lbs.

NOTE—***Installation and care of safety valves.*** All safety valves should be connected directly to the boiler with a close nipple or a short steam nozzle of the full valve size, or larger. In attaching the flange, the bolts should be drawn up evenly, as distortion of the valve seat may otherwise occur. In making a hydraulic test on a boiler the valve should be properly gagged, and not made to blow at a higher pressure by screwing down the spring. Safety valve springs are designed for a definite pressure, which is usually stamped on a tag fastened to the valve. If a valve is to be set at a pressure differing from the designed pressure by more than 5 or 10 lb. (depending upon the make of the valve) either above or below, a new spring should be furnished. Where safety valves are used with superheated steam, those of the outside spring type should be used in order to protect the metal of the spring from the high temperatures. ***In operation,*** all valves should be made to blow periodically to avoid the danger of sticking.



FIGS. 30*h* and 30*i*.—Valve and seat with flat and beveled contact surface. ***For marine use*** the beveled type is the standard and the bevel must be inclined at an angle of 45°. Most engineers think that flat seats are not allowed for marine use, but this is not correct, for according to RULE II, 23—Flat seat safety valves may be used under the formula and table under the heading "Safety Valves" in Rule II.

THE VALVE AND SEAT

Classes of Valve and Seat.—There are three types of valve and seat:

1. Plain valve with seat having flat contact surface;

2. Plain valve with seat having beveled contact surface;

3. "Pop" valve with seat having either flat or beveled contact surface.

Of the three types, the latter with beveled contact surface is generally used for marine use.

How do the discharge capacities of flat and beveled valves compare?

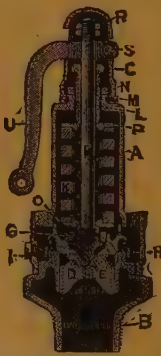
The discharge capacity of a flat valve is 1.41 times that of a 45° beveled valve of same diameter and lift.

What is a pop safety valve?

One so constructed that it opens very suddenly like a cork popping out of a bottle and remains open until the pressure is reduced a pre-determined amount.

What is the advantage of a pop valve?

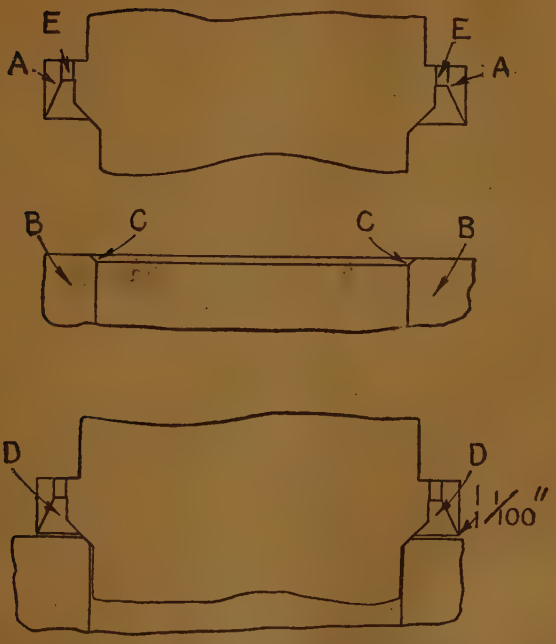
It is very sensitive in that it will blow very close to the set pressure, and also very stable in that it will not chatter but continue blowing until the pressure is appreciably reduced.



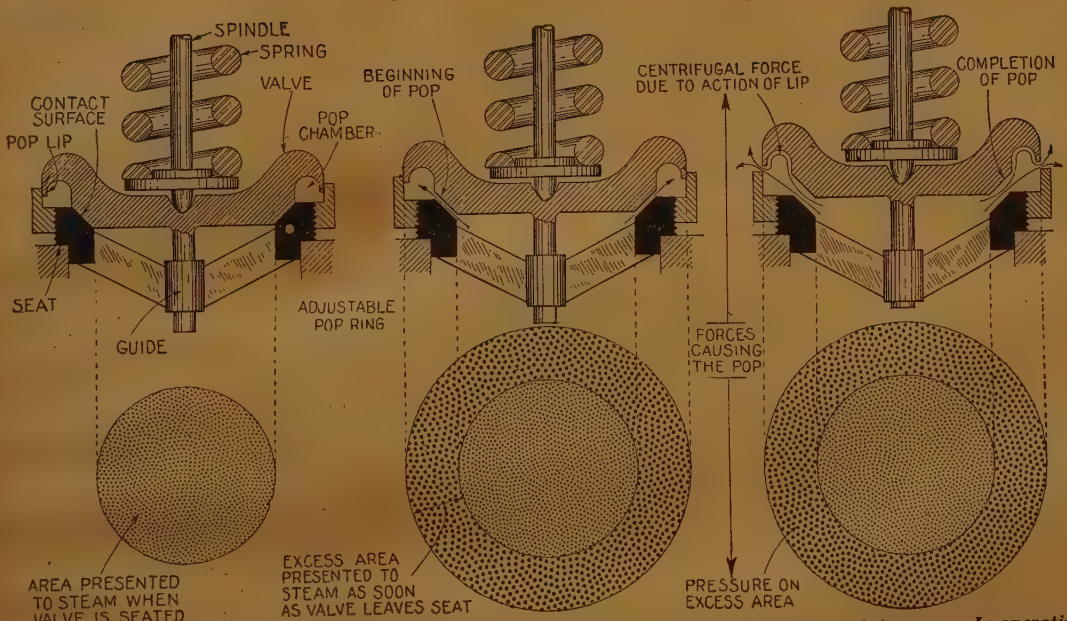
FIGS. 30*j* to 30*l*.—Lunkenheimer pop safety valves for working pressures up to 250 lbs. Fig 30*j* top outlet; fig. 30*k* sectional view; fig. 30*l*, angle outlet. These valves are made of bronz composition. All valves are provided with lock key attachment to guard against their bein tampered with, and adjustment of the amount of pop can be made from the outside of th valve without taking it apart. The springs rest between ball and socket plates, whic equally divides the pressure on the disc, and as the spring and disc are encased, the valv cannot be affected by back pressure. Lunkenheimer valves have bevel seats, at an angle o 45 degrees to the vertical axis of the valve, and are provided with suitable levers, by means o which the discs can be raised from their seats. The outlets are made one size larger tha the inlets. ***To take the valve apart:*** take out the lock screw and remove the lever U; loose screw M, and remove bonnet C; relieve the load on the spring by unscrewing the regulatin screw L; remove regulating ring screw I; then unscrew bell A. ***To set the valve*** for a high pressure, turn regulating screw L, down and for a lower pressure turn it up. ***The po*** or amount of escaping steam is regulated by the ring H, in the base of the valve, which easily accessible without taking the valve apart, and is held securely in place, when set, b the regulating ring screw I, on the side of the bell. If the valve do not relieve the pressu enough, remove screw I, and turn the ring H, up, which covers the drill holes and cause the disc to lift higher and remain longer off its seat. If the valve reduces the pressure t much, turn the ring H, down. When the desired adjustment is obtained, secure the rin by means of the screw I.

What names are given to the pressures at which the valve opens and at which it closes?

The *blow off* and the *blow down* pressures respectively.



FIGS. 30*m* to 30*o*.—Construction of Ashton pop valve and seat. Fig 31*m* outline of a portion of the wing part of valve. A, represents the knife edge pop lip and E, the supplementary relief holes in the top of the pop chamber. Fig. 31*n*, portion of the bushing or valve seat to which the wing valve is nicely fitted. C, is the bevel seat as made on the bushing B, fig. 31*o*, wing valve in normal position on its seat, D, being the enclosed pop chamber thus formed. ***With this construction*** it is obvious that the wing valve must rest solidly on the ground joint at the bevel seat, therefore the knife edge lip must never touch on the bushing, otherwise the valve will leak. It is customary to carefully fit the valve when new, so that the lip will have a space below it that will permit of a thin sheet of paper being passed between it and the bushing, or so that the valves can be slightly rocked by hand. This relation of valve to bushing must be considered in making repairs. The depth of the pop chamber should be kept approximately to the original dimensions when making repairs, and the bevel seat on bushing will give the best results if maintained the same narrow width of not over one-eighth of an inch, even on the largest size valves. The relief holes E, modify the pop, or difference between the pressure at which the valve opens and that at which it closes, which is usually from three to five pounds. More holes make less pop, or *vice versa*. The pop is entirely dependent upon the amount of pressure that is accumulated in the pop chamber, the main discharge passing under the lip. Pop safety valve springs must be of proper size to suit the pressure at which the valve is to work. They cannot be used for a greater range than fifteen pounds above or below the original set pressure without materially impairing the efficiency of the valve. Lighter or heavier springs are required to be fitted for other changes of working pressures desired. The valve must always be applied close to the boiler by a short nipple or flange connection. Being sensitive in action, it requires close application to the main body of steam, otherwise it will not get sufficient supply to keep it well off its seat when blowing, to prevent chattering. In making up joints between valve and connections, red lead or other similar material used should be put on sparingly, and gaskets on flanges should be carefully trimmed to prevent any foreign material working up into the valve to clog or cause a leak.



FIGS. 30*p* to 30*r*.—Construction and operation of a ***pop*** valve. Fig. 30*p* shows the essential parts with their names. ***In operation*** as the valve begins to lift, steam rushes into the pop chamber and being confined (or partially so) therein acts on an excess area as indicated by the shaded ring, fig. 30*q*, causing the valve to suddenly lift or "pop" to its full opening as in fig. 30*r*, hence the name *pop* valve. The main object of the pop ring is to regulate the blow down or closing pressure. ***To regulate***, if valve reduce pressure too much, lower pop ring, if not enough, raise pop ring.

Describe the construction and operation of a pop valve.

As shown in fig. 30*p* the valve is provided with a projecting *pop lip* and the seat with an adjustable *pop ring* forming the *pop chamber*. *In operation* when the valve begins its opening movement, steam rushes into the pop chamber and suddenly acts on an excess area as in fig 30*q*, thus quickly accelerating the movement of the valve which opens wide with great rapidity as in fig. 30*r*.

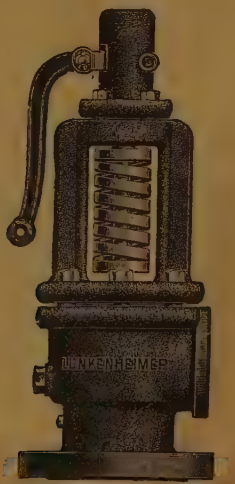


FIG. 30*s*.—Lunkenheimer ***outside spring*** pop safety valve for use with ***super-heated steam***. *An outside spring valve should* ***always*** *be used with super-heated steam as the spring is protected from the intense heat of the steam.*

When the pop chamber opens to the atmosphere what two forces tend to keep the valve open?

The pressure of the steam on the excess area presented by the pop chamber and the beveled passage way, and the centrifugal force caused by the action of the curved pop lip in changing the direction of the steam.

How is the intensity of the pop regulated?

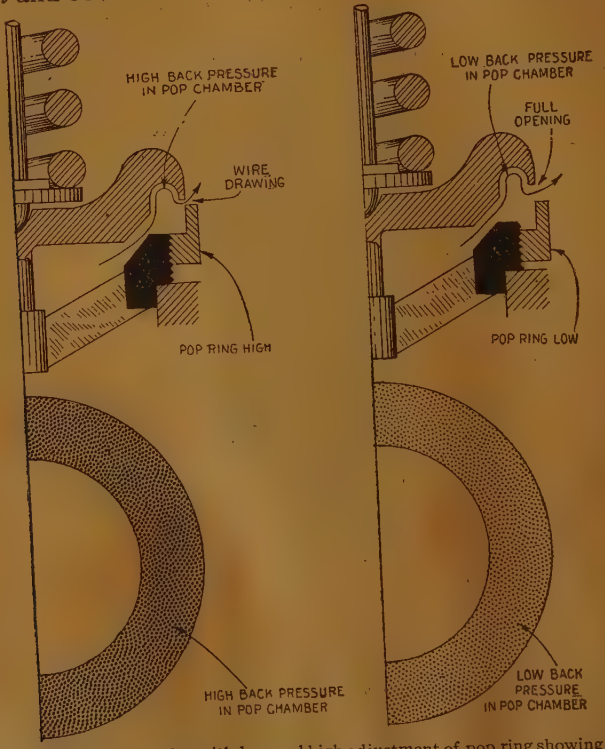
By adjusting the pop ring.

Evidently if the pop ring be screwed down so low that the pop chamber is open to the atmosphere when the valve is closed the valve will not open so suddenly as when it is adjusted to close the pop chamber when the valve is seated as in fig. 30*p*.

As usually constructed the pop ring fits loosely and the pop lip so that the pop chamber is a slight opening when ring is in high adjustment.

What is the main object of the pop ring?

To regulate the blow down or closing pressure as explained in figs. 30*t* and 30*u*.



FIGS. 30*t* and 30*u*.—Pop valve with low and high adjustment of pop ring showing ***why*** the bl down or closing pressure is governed by the position of this ring. In fig. 30*t*, the ring is high adjustment so that with the valve fully opened as shown, the opening past the rin restricted resulting in *wire drawing* of the steam with a higher back pressure in the chamber than in fig. 30*u* where the ring is in low adjustment giving free passage for the ste to the atmosphere. ***It must be evident*** that with the adjustment of fig. 30*t* giving back pressure in the pop chamber, the valve will remain open longer and reduce the bo pressure to a lower point than with the adjustment of fig. 30*u*, giving *low* back pressur the pop chamber.

SAFETY VALVE CALCULATIONS

Introduction.—Nearly every one finds more or less trouble in solving safety valve problems, which well may be called the "bridge of sighs," as, indeed, many scores and hundreds of applicants are denied a license, because they cannot correctly answer the questions relating to this requirement, and who otherwise would have passed the examination.

FIG. 30*v*.—Sectional view of Powell iron body cross pattern lever safety valve with screwed ends showing interior construction. As shown there are two inlets and one outlet. The seat consists of a bushing screwed into the valve chamber casting, the latter having a transverse bridge below which serves as an under guide for the valve. The valve spindle and guide stem are attached to the valve by screw joints as shown.

According to the General rules and Regulations prescribed by the Board of Supervising Inspectors:

RULE IV, 35.—No person shall receive an original license as engineer or assistant engineer of steam vessels (except for license as engineer of sawmill boats and pile drivers propelled by steam, and except for special license as engineer of a steam vessel of any kind of 10 gross tons or under on which a licensed engineer is required) who *is not able to determine the weight necessary to be placed on the lever of a safety valve (the diameter of valve, length of lever, distance from center*

*of valve to fulcrum, weight of lever, and weight of valve and stem being known) to withstand any given pressure of steam in a boiler, or who is not able to figure and determine the strain brought on the braces of a boiler with a given pressure of steam, the position and distance apart of braces being known** such knowledge to be determined by an examination in writing, and the report of examination filed with the application in the office of the local inspectors, and no engineer or assistant engineer now holding a license shall have the grade of the same raised without possessing the above qualifications." (Sec. 4405 R. S.)

Two Methods.—There are two methods by which the applicant for an engineer's license can prepare to answer questions on the safety valve problem.

1. By learning several rules parrot fashion, or,

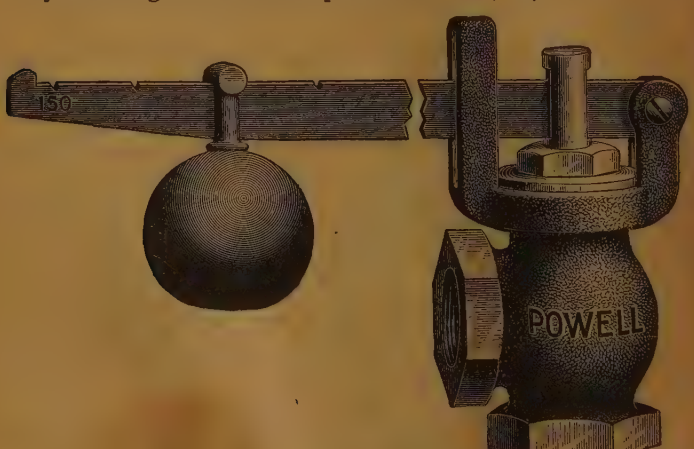


FIG. 30*w*.—Powell steam bronze angle pattern lever safety valve with screwed ends for working pressures up to 150 lbs. Showing exterior construction.

2. By *reasoning out the matter* and writing an equation from which the answer to any question the examiner may ask is easily obtained.

The man who adopts the first method, spends considerable time in memorizing the several rules, which have absolutely no meaning to him, and consequently, he does not know any more about the problem than he did at first although he may be able to recite these rules and pass the examination.

NOTE—While the boiler brace problem does not properly belong under the heading "Safety Valve Calculations" it is explained at the end of this section for the convenience of the reader as these items constitute the most important "*figuring*" to be encountered in the examination

Again, the man who can solve the problem by the second method *understands* what he is talking about; he knows *why* a given weight must be placed at a certain point for the valve to blow at a given pressure. Moreover, he commands *respect* rather than *tolerance* from the examiner.*

FIG. 30x.—Ashton duplex cam lever marine pop safety valve with lock up attachment.

Unfortunately, those with very limited knowledge of mathematics are unable to learn how to construct and solve an equation without considerable study, but the author believes, in most cases, that the time spent in committing to memory meaningless rules, could be far better utilized in studying the principles of the problem and thus acquire some *real knowledge* rather than *artificial knowledge*.

*NOTE—Unfortunately, some of the Government authorities, presumably to facilitate the work of their examiners by having safety valve problems worked out in the same order, insist that the problems be worked according to the so called ***Roper's rules.*** *It should be distinctly understood* that Roper did not originate any "rules" but simply stated safety valve principles in the form of rules, indicating a certain *order* in which the various operation of multiplication, division, etc., are to be performed in solving the problems, just as he might say $3 \times 5 = 15$, while some other writer would express it $5 \times 3 = 15$, the result being the same in either case.

RULE II, 23.—Whenever the area of a safety valve, as found by the rule of this section will be greater than that corresponding to 4½ inches in diameter, two or more safety valves, the combined area of which shall be equal at least to the area required, shall be used.

Safety Valve Rules as stated by Roper

(Edited and revised)

1.—To find the weight necessary to put on a safety valve lever, when the area of valve, pressure, etc., are known.

RULE.—A, *Multiply the area of valve by the pressure in pounds per square inch;* B, *multiply this product by the distance of the valve from the fulcrum;* C, *multiply the weight of the lever by one-half its length (or its center of gravity);* D, *multiply the weight of valve and stem by their distance from the fulcrum;* E, *add these last two products together;* F, *subtract their sum from the second product, and divide the remainder by the length of the lever; the quotient will be the weight required.*

2.—To find the pressure per square inch when the area of valve, weight of ball, etc., are known.

RULE.—A, *Multiply the weight of ball by the length of lever;* B, *multiply the weight of lever by one-half its length (or the distance from the fulcrum to its center of gravity);* C, *multiply the weight of valve and stem by the distance from fulcrum;* D, *add these three products together;* E, *this sum divided by the product of the area of the valve, and its distance from the fulcrum, will give the pressure in pounds per square inch.*

3.—To find the distance from the fulcrum at which the weight should be placed for a given blowing off pressure.

RULE.—A, *Multiply the area of the valve in square inches by the steam pressure per square inch;* B, *subtract the weight of the valve and stem in pounds;* C, *multiply the difference by the distance from the valve to the fulcrum in inches;* D, *from this product, subtract the product of the weight of the lever by the distance of its center of gravity from the fulcrum;* E, *this difference, divided by the weight of the ball in pounds, will give the required distance in inches.*

4.—To find the distance of the center of gravity of taper levers from the fulcrum.

RULE.—A, *To the width of the small end of the lever add one-third of the difference between the large and the small ends of the lever;* B, *multiply this sum by the length of the lever;* C, *divide the product by the sum of the large and the small end of the lever, all in inches. The quotient will be the required distance in inches.*

Problem.—RULE 1, fig. 30*y*.

Given: Area valve 7.07 sq. ins. Weight of valve and spindle =8 lbs.; weight of lever, 24 lbs.; distance fulcrum to spindle, 4 ins.; distance fulcrum to center of gravity of lever, 16 ins.; distance fulcrum to ball, 2.02 ins. Steam pressure 60 lbs.

Find: *Weight of ball.*

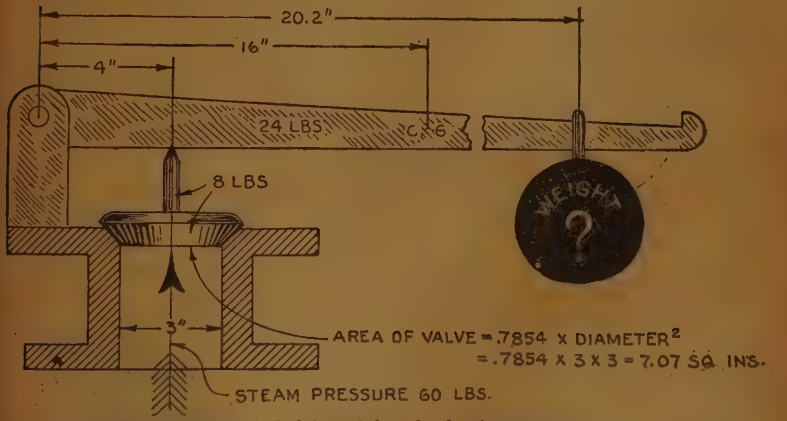


FIG. 30*y*.—***Problem Rule 1:*** *To find the* ***weight*** *to be placed on a safety valve.*

A. First step

7.07 sq. ins. area of valve
60 lbs. per sq. in., steam pressure
424.20 lbs.

This gives the ***total pressure*** *due to the* ***steam*** *acting on the valve.*

B. Second step

424.2 lbs. total pressure on valve
4 ins. distance valve to fulcrum
1,696.8

This is the ***steam moment*** *tending to* ***open*** *the valve.*

C. Third step

24 lbs. weight of lever
16 ins. distance from fulcrum to center of gravity of lever
144
24
384

This is the ***lever moment*** *tending to* ***close*** *the valve.*

D. Fourth step

8 lbs. weight of valve and spindle
4 ins. distance fulcrum to spindle
32

This is the ***valve and spindle moment*** *tending to* ***close*** *the valve.*

E. Fifth step

384 lever moment from **C**
32 valve and spindle moment from **D**
416

This is the sum of the ***lever moment*** and the ***valve and spindle moment.***

F. Sixth step

1,696.8 steam moment from **B**
416 lever moment + valve and spindle moment
1,280.8

20.2)1280.8(63.41
1212
688
606
820
808
1200

This is the ***required weight*** *necessary to put on the lever at the* ***given distance*** *for the valve to* ***blow*** *at 60 lbs.*

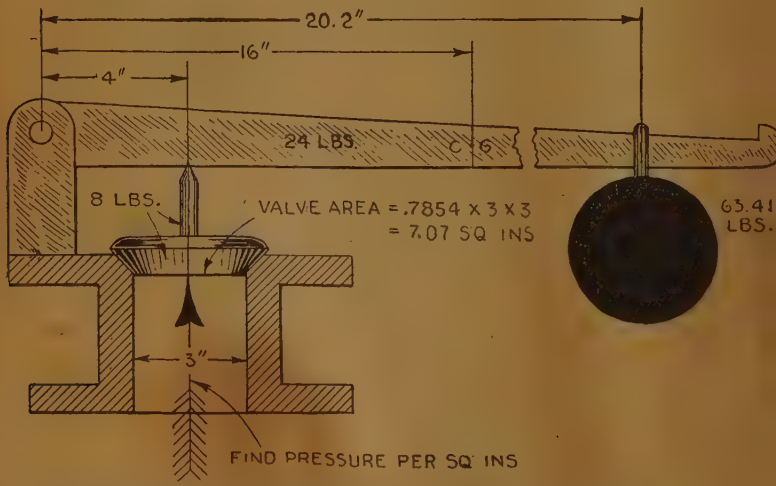


FIG. 30z.—***Problem Rule 2: To find steam pressure at which valve will blow.***

Problem.—RULE 2, fig. 30z.

Given: Area of valve 7.07 sq. ins.; weight of valve and spindle 8 lbs.; weight of lever 24 lbs.; weight of ball 63.41 lbs.; distance fulcrum to spindle 4 ins.; distance fulcrum to center of gravity of the lever 16 ins.; distance fulcrum to ball 20.2 ins.

Find: *Steam pressure at which valve will blow.*

A. First step

63.41 lbs. weight of ball
20.2 ins. distance from fulcrum to ball

12 682
1268 2
1280.882

This is the ***ball moment*** *tending to* ***close*** *the valve.*

B. Second step

24 lbs. weight of lever
16 ins. distance from fulcrum to center of gravity of lever

144
24
384

This is the ***lever moment*** *tending to* ***close*** *the valve.*

C. Third step

8 lbs. weight of valve and spindle
4 ins. distance from fulcrum to spindle

32

This is the ***valve and spindle moment*** *tending to* ***close*** *the valve.*

D. Fourth step

1280.88 ball moment (product A)
384 lever moment (product B)
32 valve and spindle moment (product C)

1696.88

This is the ***sum*** *of the* ***three moments*** *(calculated in* **A, B,** *and* **C**) *tending to* ***close*** *the valve.*

E. Fifth step

7.07 area of valve
4 distance from fulcrum

28.28)1696.88(60 lbs.
1696.8
8

This is the ***required pressure*** *at which the valve will* ***blow.***

Problem.—RULE 3, fig. 31*a*.

Given: Area of valve 7.07 sq. ins.; weight of valve and spindle 8 lbs.; weight of lever 24 lbs.; weight of ball 63.41 lbs.; distance fulcrum to center of gravity of the lever 16 ins.; steam pressure 60 lbs.

Find: *Distance of ball from the fulcrum.*

RULE II, 23.—Safety valves when fitted either to the shell of boiler or steam drum may be fitted with internal dry pipes when made of standard steam pipe or of riveted material equal in thickness, and when the combined openings in the dry pipe equal in area at least one and one-half times the opening of the valve.

A. First step

7.07	sq. ins. area of valve
60	lbs. steam pressure per sq. in.
424.20	

*This is the **total pressure** due to the steam acting on the valve.*

B. Second step

424.2	total pressure on valve
8	weight of valve and spindle
416.2	

*This is the **net pressure** actin **upward** on the valve allowing fo weight of valve and spindle.*

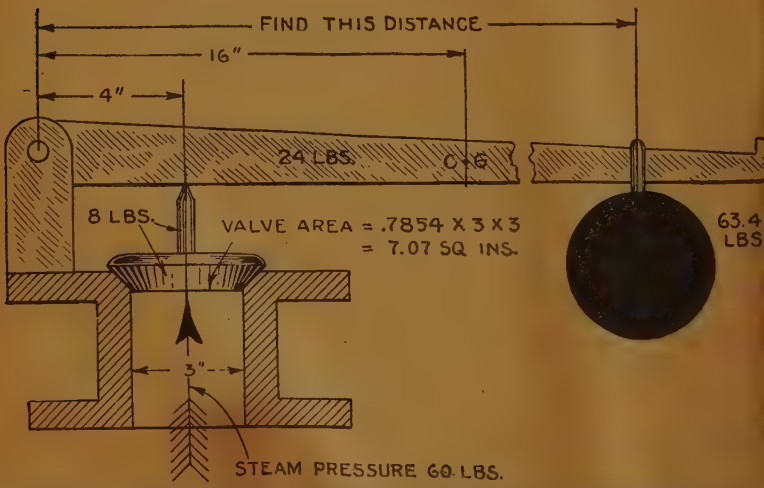


FIG. 31a.—***Problem Rule 3:** To find **distance** from the fulcrum at which the weight must placed.*

C. Third step

416.2 lbs.	net upward pressure on valve
4 ins.	distance from fulcrum to valve
1664.8	

*This is the **net steam moment** tending to open the valve.*

D. Fourth step

24	lbs. weight of lever
16	ins. dist. from center of gravity to fulcrum
144	
24	
384	

*This is the **lever moment** tendi to close the valve.*

1664.8 steam moment (product C)
384 lever moment (product D)
1280.8

This is the difference between the ***steam*** and ***lever*** moments.

E. Fifth step

Divide difference between ***steam*** and ***lever*** moments found in **D** by weight of ball, *i.e.*

steam moment − lever moment ÷ weight of ball

63.41)1280.8(20.2 ins.
1268 2
12 600

This is the ***required distance*** *from the fulcrum at which the ball must be placed for the valve to blow at 60 lbs. pressure.*

Problem.—Rule IV, fig. 31*b*.

Given: Width of small end of lever ½ in.; width of large end 3 ins.; length of lever 30 ins.

Find: *Center of gravity of lever.*

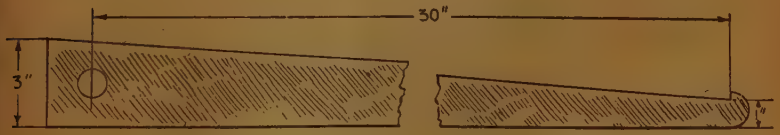


FIG. 31*b*.—***Problem Rule 4:*** *To find the* ***center of gravity*** *of the lever.*

A. First step

3 large end
1 small end
3)2 difference
.667 one-third difference
1. small end
1.667 small end + ⅓ difference

B. Second step

1.667 sum from A
30 length of lever
50.010

C. Third step

3 large end
1 small end
4 sum of ends
4)50.01 product from B
12.5 ins.

This is the required ***distance*** *of the center of gravity from the fulcrum.*

Principle of the Safety Valve.—When a boiler is in operation there are four forces acting on a lever safety valve, of which, one *tends to* **raise** *the valve off its seat* and the other three *tend to keep it* **closed;** when the first force slightly exceeds the sum of the other three forces, the valve will open and allow the steam to escape. The four forces just mentioned may be described as follows:

1. The force due to the steam *which tends to* **open** *the valve;*

It is equal to the area of the valve in square inches multiplied by the steam pressure as indicated by the steam gauge.

2. The force due to the weight of the valve and spindle, *which tends to* **close** *the valve;*

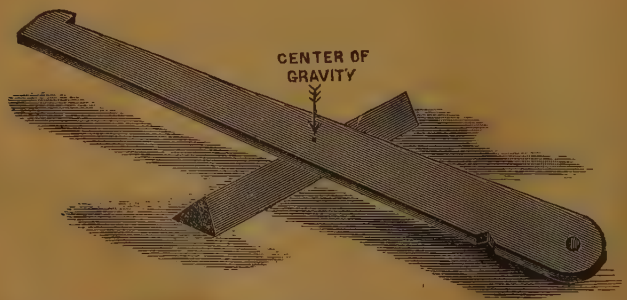


FIG. 31*c*.—Method of finding the center of gravity of the lever. The center of gravity of the lever is the point where the bar would be in equilibrium if balanced over a knife edge or any other support with a sharp corner placed at right angles to the lever, as shown in the figure.

3. The force due to the weight of the lever, *which tends to* **close** *the valve;*

4. The force due to the weight of the ball, *which tends to* **close** *the valve.*

These forces act at different distances from a point called the *fulcrum*, which corresponds to the point F, in fig. 31*d*, about which the lever turns. As indicated in the figure, the four forces are as follows:

S = *total* pressure due to the steam tending to raise the valve;

This is equal to the steam pressure indicated by the steam gauge multiplied by the area of the valve. The area of the valve is equal to its diameter squared, multiplied by .7854.

V = weight of valve and spindle;

G = " " lever;

B = " " ball.

The distances at which these forces act are:

v = distance from fulcrum to center of the valve;

g = " " " " center of gravity of the lever;

b = distance from fulcrum to the ball.

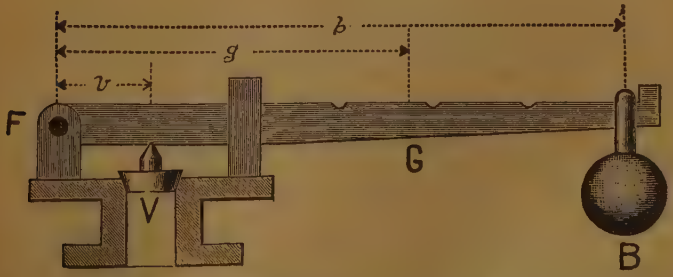


FIG. 31*d*.—Lever safety valve with dimensions, etc., necessary in making calculations. *b*, Distance from fulcrum to ball; *g*, distance fulcrum to center of gravity of lever; *v*, distance fulcrum to spindle; F, fulcrum; V, weight of valve and spindle; G, weight of lever; B, weight of ball.

The weights are measured in pounds, and the distances in inches.

The weight of the lever is considered as acting at its center of gravity *g*, distance from the fulcrum.

The center of gravity of the lever is that point where it would be in equilibrium if balanced over a knife edge or any other support with an edge, as in fig. 31*c*.

Now, since all of these forces do not act along the axis or central point of the valve (fig. 31*d*), it is necessary to determine the *tendency of the several forces to produce rotation of the lever about the fulcrum F.*

In order to determine this, the *moments* of the several forces with respect to the fulcrum F must be determined.

In mechanics the ***moment*** *of a force* is a *measure of its* ***effect*** *in producing* ***rotation*** *about a fixed point.*

The moment of a force, with respect to a point, is the product of the force multiplied by the perpendicular distance from the point to the direction of the force.

The fixed point corresponding to the fulcrum F, fig. 31*d*, is called the *center of moments*, and the ***horizontal*** distance, *v*, *g*, or *b*, *the lever arm* or *leverage* of the force.

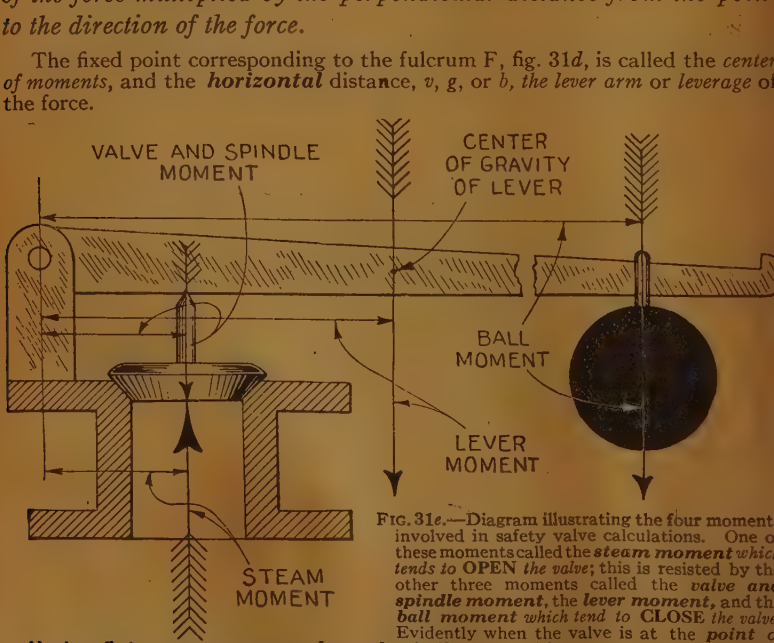


FIG. 31*e*.—Diagram illustrating the four moments involved in safety valve calculations. One of these moments called the ***steam moment*** *which tends to* **OPEN** *the valve*; this is resisted by the other three moments called the ***valve and spindle moment***, the ***lever moment***, and the ***ball moment*** *which tend to* **CLOSE** *the valve*. Evidently when the valve is at the ***point of blowing off***, the ***steam moment=valve and spindle moment+lever moment+ball moment***. Evidently if the steam pressure increase a very small amount sufficient to cause the steam moment to overcome the ***friction*** *of the mechanism*, the valve will open and blow off.

The moment of the ball B in fig. 31*d* with respect to the fulcrum F, for instance, is equal to the weight of the ball multiplied by its distance from F; that is, moment of the ball = B × *b* or simply B*b*.

The four moments to be considered in solving the safety valve problem are as follows:

1. Moment due to the ***steam;***

It is equal to the *total* pressure of the steam acting on the valve multiplied by the distance from fulcrum to center of valve; that is, in fig. 31*d*, ***steam moment*** = S*v*.

2. Moment due to the *weight* of the ***valve and spindle;***

It is equal to the weight of the valve and spindle multiplied by the distance from fulcrum to center of valve; that is, ***valve and spindle moment*** = V*v*.

3. Moment due to the weight of the ***lever;***

It is equal to the weight of the lever multiplied by the distance from the fulcrum to the center of gravity of the lever; that is, ***lever moment*** = G*g*.

4. Moment due to the weight of the ***ball.***

It is equal to the weight of the ball multiplied by the distance from the fulcrum to the ball; that is, ***ball moment*** = B*b*.

Now, when the valve is at the ***point*** *of blowing off*, the first moment *which tends to* ***raise*** *the valve* will equal the sum of the other three moments *which tend to keep the valve* ***closed;*** that is:

$$\left.\begin{matrix}\textbf{steam}\\ \textbf{moment}\\ S \times v\end{matrix}\right\} = \left\{\begin{matrix}\textbf{valve and}\\ \textbf{spindle moment}\\ V \times v\end{matrix}\right\} + \left\{\begin{matrix}\textbf{lever}\\ \textbf{moment}\\ G \times g\end{matrix}\right\} + \left\{\begin{matrix}\textbf{ball}\\ \textbf{moment}\\ B \times b\end{matrix}\right.$$

RULE II, 23.—The areas of all safety valves on boilers contracted for or the construction of which commenced on or after June 1, 1904, shall be determined in accordance with the following formula and table:

$$\text{Formula: } a = .2074 \times \frac{W}{P} \qquad (1)$$

Where a = area of safety valve, in square inches, per square foot of grate surface.
W = pounds of water evaporated per square foot of grate surface per hour.
P = absolute pressure per square inch = working gauge pressure + 15.

When this calculation results in an odd size of safety valve, use next larger standard size.

EXAMPLE.

Boiler pressure = 75 pounds per square inch (gauge).

2 furnaces: Grate surface = 2(No.) × 5 feet 6 inches (long) × 3 feet (wide) = 33 square feet.

Water evaporated per pound of coal = 8 pounds.

Coal burned per square foot grate surface per hour = 12½ pounds.

Evaporation per square foot grate surface per hour or W, = 8 × 12½ = 100 pounds. P = 75 + 15 = 90 lbs. absolute.

From equation (1)

$$a = .2074 \times \frac{100}{90} = .23 \text{ cu. ins.}$$

Therefore area of safety valve = 33 × .23 = 7.59 square inches.

For which the diameter is 3⅛ inches nearly.

or simply: $$Sv = Vv + Gg + Bb.$$

This is the safety valve equation with which any problem is easily solved. In working out an example, the given values are

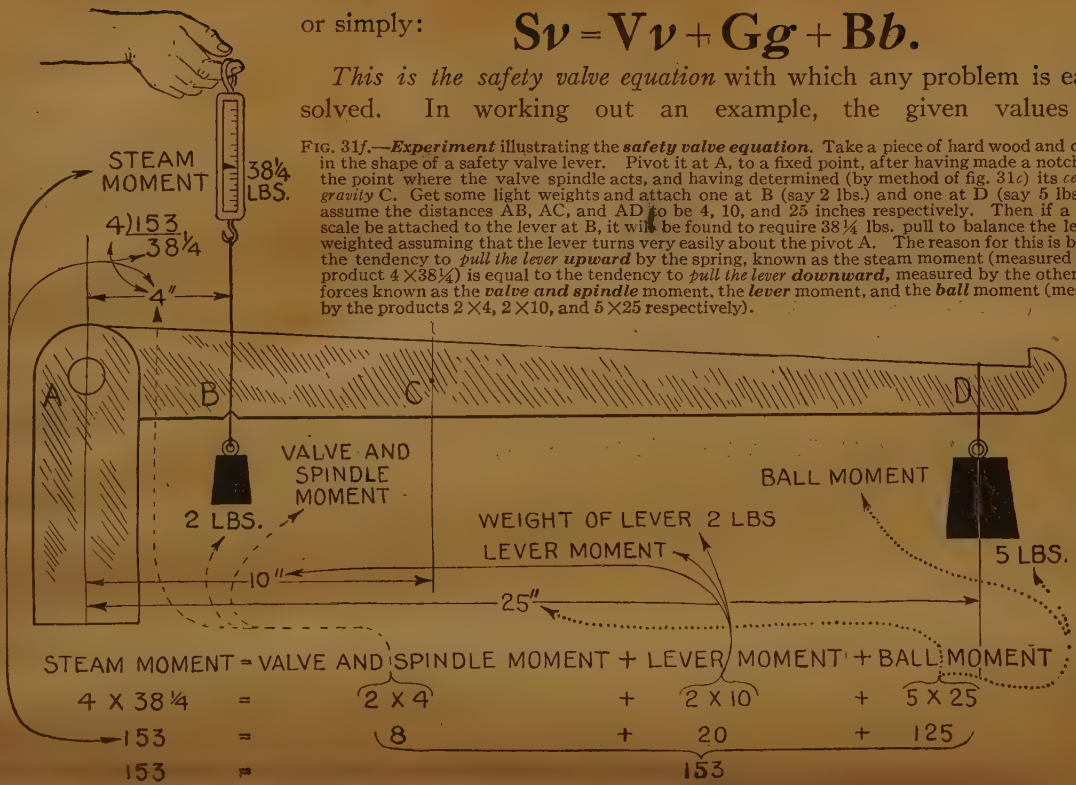


FIG. 31*f*.—***Experiment*** illustrating the ***safety valve equation***. Take a piece of hard wood and cut out in the shape of a safety valve lever. Pivot it at A, to a fixed point, after having made a notch at B, the point where the valve spindle acts, and having determined (by method of fig. 31*c*) its *center of gravity* C. Get some light weights and attach one at B (say 2 lbs.) and one at D (say 5 lbs.) and assume the distances AB, AC, and AD to be 4, 10, and 25 inches respectively. Then if a spring scale be attached to the lever at B, it will be found to require 38¼ lbs. pull to balance the lever as weighted assuming that the lever turns very easily about the pivot A. The reason for this is because the tendency to *pull the lever* ***upward*** by the spring, known as the steam moment (measured by the product 4 × 38¼) is equal to the tendency to *pull the lever* ***downward,*** measured by the other three forces known as the ***valve and spindle*** moment, the ***lever*** moment, and the ***ball*** moment (measured by the products 2 × 4, 2 × 10, and 5 × 25 respectively).

substituted for the letters and the equation solved for the unknown letter.

Example:—What weight ball must be put on a 3″ safety valve so that it will blow at 100 lbs., if the weight of valve and spindle be 8 lbs., lever, 24 lbs., distance of valve from fulcrum 4″; distance of center of gravity from fulcrum 16″; distance from fulcrum to ball 38″.

S, the total pressure tending to raise the valve is equal to the steam pressure multipiled by the area of the valve in square inches = 100 × diam. × diam. × .7854 = 100 × 3 × 3 × .7854 = 706.9 lbs., say 707 lbs.

Now write out the equation and substitute the values given in the example and value just found for S, under the proper letters, thus:

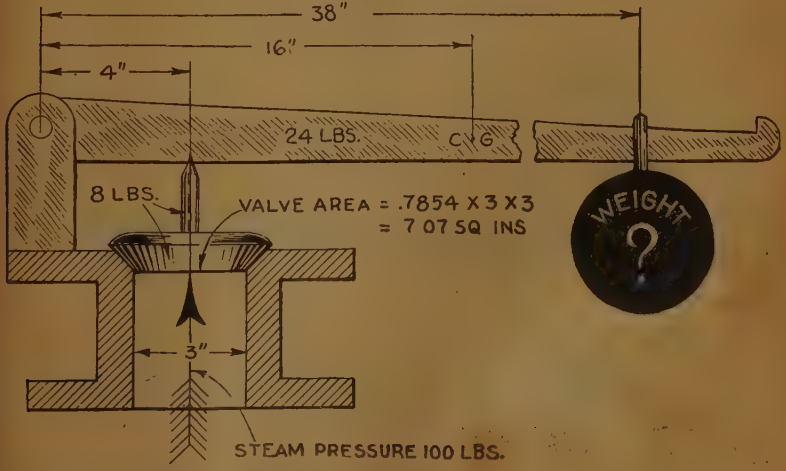


FIG. 31*g*.—***Example:*** *To find what weight* must be put on the safety valve when the conditions are as indicated in the figure.

$$\underbrace{Sv}_{707\times4} = \underbrace{Vv}_{8\times4} + \underbrace{Gg}_{24\times16} + \underbrace{Bb}_{B\times38}$$

multiplying

$$2{,}828 = 32 + 384 + 38B$$

and adding

$$2{,}828 = 416 + 38B$$

The equation must be "solved for B," which means that everything must be transferred to the left hand side of the equality sign except the B. The first step then is to get the 416 on the left hand side; to do this, subtract 416 from both sides, thus:

$$2{,}828 = 416 + 38B$$
$$\underline{416} \quad \underline{416}$$
$$2{,}412 = \quad 38B$$

As it now stands, $2{,}412 = 38B$, or in other words, $38B = 2{,}412$:

Now, divide both sides by 38, thus:

$$\frac{38B}{38} = \frac{2{,}412}{38}, \text{ hence:}$$

$$B = \frac{2{,}412}{38} = 63.4 \text{ lbs., weight of ball.}$$

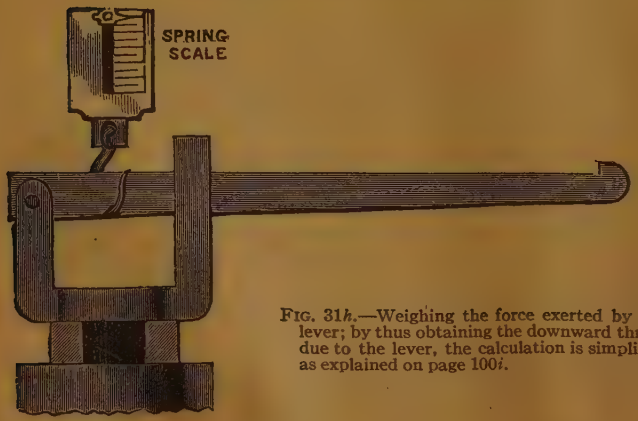


FIG. 31*h*.—Weighing the force exerted by the lever; by thus obtaining the downward thrust due to the lever, the calculation is simplified as explained on page 100*i*.

RULE II, 23.—*Examples continued.*

Boiler pressure=215 pounds.

6 furnaces: Grate surface=6 (No.) ×5 feet 6 inches (long) ×3 feet 4 inches (wide)=11(square feet.

Water evaporated per pound coal=10 pounds.

Coal burned per square foot grate surface per hour=30 pounds.

Evaporation per square foot grate surface per hour=10×30=300 pounds.

Hence W=300, P=215+15=230 lbs. absolute.

$$A = .2074 \times \frac{300}{230} = .27$$

Therefore area of safety valve=110×.27=29.7 square inches, which is too large for on valve. Use two.

$\frac{29.7}{2}$=14.85 square inches. Diameter=4⅜ inches.

When the engineer has to solve a safety valve problem in actual practice, he may do so without finding the center of gravity of the lever, if he use a spring balance as in fig. 31*h*.

The balance should be hooked under the point at which the valve spindle acts and then by pulling up on the balance, the actual downward pressure of the lever *at this point* can be determined. To this weight should be added the weight of the valve and spindle.

The forces then will be as in fig. 31*i*, from which the equation is:

$$Sv = Mv + Bb$$

here M, is equal to the sum of the pressure of the lever as indicated on the scale and spring fig. 31*h*, plus the weight of the valve and spindle; the other letters are as before.

If the weight of the ball, or its distance from the fulcrum be required, the equation can be still further simplified by letting

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RULE 11, 23.—*Examples continued.*

To determine the area of a safety valve for boiler using oil as fuel or for boilers designed for any evaporation per hour:

Divide the total number of pounds of water evaporated per hour by any number of pounds of water evaporated per square foot of grate surface per hour (W) taken within the limits of 100 to 380 lbs. This will give the equivalent number of square feet of grate surface for boiler for estimating the area of valve. Then proceed as before.

EXAMPLE.

Required the area of a safety valve for a boiler using oil as fuel, designed to evaporate 8,000 pounds of water per hour, at 175 pounds gauge pressure.

Make W=200.

$\frac{8,000}{200}$ =40, the equivalent grate surface, in square feet

For W=200, and P=175+15=190 lbs.

$$A = .2074 \times \frac{200}{190} = .218$$

and .218×40=8.72 square inches, the total area of safety valve required for this boiler, for which the diameter is $3\frac{1}{16}$ inches nearly.

M, in fig. 31*i*, represent the *sum* of the pressure of the lever as indicated on the spring scale plus the weight of the valve and spindle, subtracted from the *total* pressure of the steam on the valve. The equation then becomes

$$\mathbf{M}v = \mathbf{B}b$$

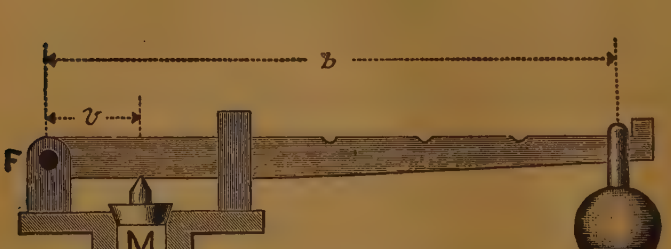


FIG. 31*i*.—Lever safety valve with dimensions, etc., necessary in making calculations where the thrust due to the lever is determined by a spring balance as in fig. 31*h*. *b*, distance fulcrum to ball; *v*, distance fulcrum to valve; M=S—L, that is, the total pressure due to the steam tending to raise the valve, less the downward thrust due to the lever as measured in fig. 31*h*; F, fulcrum; B, weight of ball.

STAYS

In ascertaining the pressure which is carried on the flat surface of a boiler, choose three stays as ABC, in fig. 31*j*. Measure from A, to B, and from A, to C. The product of these measurements is the number of square inches held by one stay; then proceed as in the following rule and example:

To find the pressure on a certain number of stay bolts on a boiler.

RULE.

Find the number of square inches enclosed by four adjacent bolts and multiply this area by the pressure of the steam as indicated

by the steam gauge. This will give the strain on one bolt. Multiply this by the number of bolts upon which it is desired to find the strain, and the result will be the answer to the question.

Example.

Suppose that the bolts are 4 inches apart, and that the gauge

---

RULE II, 16.—All holes for stays shall be drilled and no part punched.

The maximum working pressure in pounds allowable per square inch of cross-sectional area for stays used in the construction of marine boilers where same are accurately fitted normal to supported surfaces and properly secured shall be ascertained by the following formula:

$$P = \frac{A \times C}{a}$$

Where P=working pressure in pounds.

A=least cross-sectional area of stay in inches.

a=area of surface supported by one stay in inches.

C=a constant.

C=9,000 for tested steel stays 1 inch and upward in diameter when such stays are not forged or welded. The ends may be upset to a sufficient diameter to allow for the depth of the thread. The diameter shall be taken at the bottom of the thread, provided it is the least diameter of the stay. All such stays after being upset shall be thoroughly annealed.

C=8,000 for a tested Huston or similar type of brace, the cross-sectional area of which exceeds 5 square inches.

C=7,000 for such tested braces when the cross-sectional area is not less than 1.227 and not more than 5 square inches, provided such braces are prepared at one heat from a solid piece of plate without welds.

C=7,500 for wrought-iron stays 1 inch and upward in diameter when made of the best quality of refined iron. The ends may be upset to allow for the depth of the thread. The diameter shall be taken at the bottom of the thread, provided it is the least diameter of the stay. Such stays may be welded.

C=6,000 for welded crow foot stays when made of best quality of refined wrought iron, and for all stays not otherwise provided for when made of the best quality of refined iron or of steel without welds.

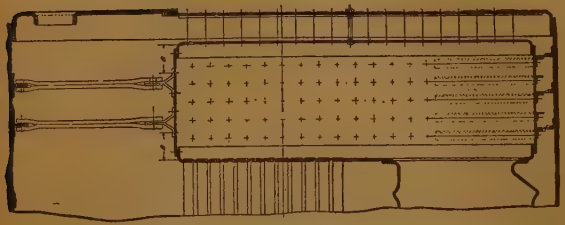
EXAMPLE.

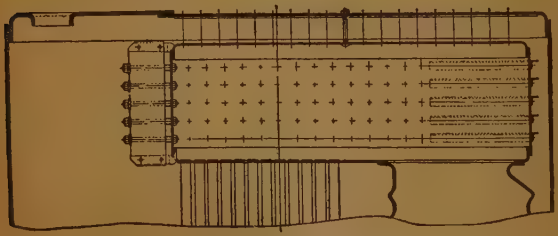
Required the working pressure of a stay 1 inch in diameter, pitched 6 inches by 6 inches center to center.

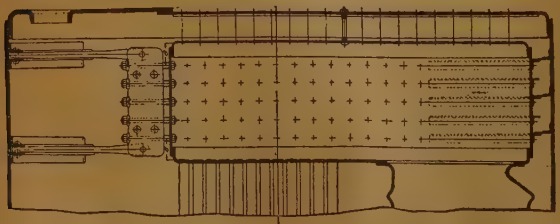
$$\text{Working pressure} = \frac{(1 \times 1 \times .7854) \times 6{,}000}{6 \times 6} = 130.9 \text{ pounds.}$$

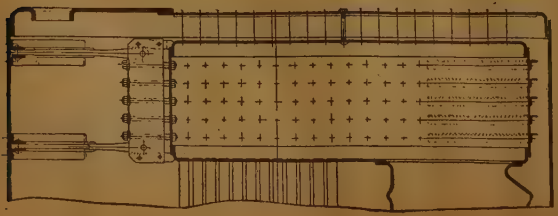
Stay bolts and stays made of the best quality of refined wrought iron may be welded. The lengthening of steel stays by welding shall not be allowed.

FIGS. 31*k* to 31*n*.—Stay loading, fig. 31*k*, full load on tube sheet and back plate; fig. 31*l*, nearly whole compression load taken off tube sheet; fig. 31*m*, nearly whole compression load taken off tube sheet; fig. 31*n*, tube sheet and back plate get full load.









RULE II, 16.—*Stays continued.*

Where

A=sectional area of pin.

D=depth from edge of pin-hole to end of leg.

2T=thickness of two angles.

EXAMPLE.

Diameter of sling stay, 2 inches. Diameter of pin, 1.6 inches. Thickness of angle, seven eighths of an inch. Required the depth from edge of pin hole to end of leg.

Substituting values and solving:

$$D=\frac{.7854\times1.6\times1.6}{2\times.875}$$

$$=1.15 \text{ inches.}$$

Minimum diameter of rivets shall be found as follows:

$$\text{Minimum diameter}=\sqrt{\frac{\text{load}}{.7854\times12{,}000\times N}}$$

Where N, equals number of rivets. Rivets shall be staggered in each leaf.

QUESTIONS AND ANSWERS FOR MARINE ENGINEERS.

CHAPTER ONE.

FUNDAMENTAL PRINCIPLES.

I. Force and Work.

1. What is Force?

Force is that which causes acceleration or retardation of a body by push or pull.

2. How is Force measured?

Force is measured by weight, or in terms of pounds or tons.

3. What is the fundamental conception of Force?

Force is conceived in terms of the influence of gravity, which gives the pressure of a body on such a support as the pan of a scale.

4. What would be the result if a body were left free to the influence of Gravity?

If a body were left free to the influence of gravity, it would travel or fall with increasing rapidity until it met a resistance.

5. What is Acceleration?

Acceleration is the increase in the rapidity of travel or fall.

6. What is the rate of the acceleration due to Gravity?

The rate of acceleration due to gravity is, at 40° latitude, equal to 32.16 feet per second. In all formulæ for calculating motion it is indicated by the letter *g*.

7. What is Mass?

Mass is the quotient found by dividing the weight of a body, in pounds, by 32.16.

8. Why is Mass used in mechanical calculations?

Mass is used for comparison; as every force expressed in pounds, divided by the acceleration in feet per second, is equal to the mass, or to the weight of the moving body divided by 32.16.

9. What is Velocity?

Velocity is the rate at which a body travels through space in the unit of time. This rate is usually expressed as feet per second.

10. What is Resistance?

Resistance is the opposite of force.

11. How does Resistance show itself?

Resistance may show itself in reaction by a solid support, by tension in a cord or rod or by friction in the guide-path of a moving body.

12. What is Power?

Power is the rate at which a force acts in the unit of time. It is, therefore, equal to force in pounds, multiplied by velocity in feet.

13. What is the unit in measurement of Power?

The unit of power is the foot-pound, or the product of a force of one pound and a velocity of one foot per time unit, which is usually a second.

14. What is Work?

Work is the total amount of power acting during a certain period of time, or the product of force in pounds and the distance in feet traveled or fallen through. If a body weighing 10 pounds falls 10 feet, it has done 100 foot-pounds of work.

15. What is Horse-power ?

Horse-power is a measure of power equal to 550 foot-pounds per second, or 33,000 foot-pounds per minute.

It is used because it can express large power more conveniently than can the foot-pound.

16. What is Energy ?

Energy is the capacity for doing work.

17. What is a Machine ?

A machine is an apparatus for giving a force opportunity to travel in a fixed path, thereby producing work that can be usefully employed.

For example : The marine steam engine is a machine that enables the pressure of steam to exert itself in the propulsion of ships.

II. Energy and Heat.

18. What is the source of all energy ?

The source of all energy is the heat of the sun's rays.

19. What are the most familiar forms of energy ?

The forms of energy from the solar heat are :

(1.) The muscular energy of animated organism produced by warmth and food.

(2.) The energy of air currents produced by the different density and temperature of the air strata.

(3.) The energy of falling water, which has been transferred

into vapor form by the heat of the sun and lifted to the clouds.

(4.) The energy of fuel, as stored in oil, wood and coal by the heat of the sun.

20. What is conservation of energy?

Conservation of energy is the observed fact that no energy is ever lost, but that the sum total of energy always remains the same.

21. How can energy be transformed?

Energy can be transformed from one expression to another in a multitude of ways. Mechanical work can be transformed into heat, electricity, light, etc., and these again into mechanical work.

The energy of animals, wind and water are directly available for mechanical work with the help of machines.

The energy of fuels is available only by the chemical process of combustion, which liberates the heat in sensible form. This sensible heat is then, by the help of a suitable agent, convertible into mechanical work by a machine.

22. What agent is employed in the marine steam engine?

Steam is the agent. It absorbs in the boiler the liberated heat of combustion and turns it into useful work in the engine.

23. What is the mechanical equivalent of heat?

The mechanical equivalent of heat is the number of foot-pounds equal to the energy stored in one thermal unit, which for English measure is given as 778 foot-pounds.

24. What is a thermal unit?

The thermal or heat unit is the quantity of heat required to raise one pound of pure, distilled water through one degree

Fahrenheit, from 39.1 degrees, which is the temperature of the maximum density of water.

25. Do all substances require the same amount of heat for raising their temperature one degree?

No; most substances require less heat than water, and for this reason water is used as the standard of comparison; its specific heat being unity.

26. How is sensible heat measured?

Sensible heat is measured by a thermometer.

27. What is a Thermometer?

A thermometer is an instrument for showing the expansion of a column of mercury in reference to the boiling and freezing points of pure, distilled water.

On the Fahrenheit thermometer water boils at 212 degrees and freezes at 32 degrees above the zero mark. The column between these two points is divided into 180 divisions or degrees.

28. How does heat affect most substances?

Increase of heat expands, decrease of heat contracts most substances.

29. How does heat affect liquids at their boiling points?

At the boiling point liquids not only expand but change the liquid state to the gaseous state.

30. How does heat affect substances at the freezing point?

At the freezing point liquids not only contract but change the liquid state to the solid state?

31. Are these boiling and freezing or melting points the same for all substances?

No; they vary greatly, which is the reason that we can boil water in an iron pot.

32. What is Latent Heat?

Latent heat is that amount of heat needed to produce the transfer from the solid to the liquid, or the liquid to the gaseous state, while no increase or decrease of temperature takes place. It refers to the number of heat units absorbed in "interior work," without affecting the sensible heat, or temperature.

33. How is heat transmitted?

Heat is transmitted by radiation or by conduction.

34. What is Radiation of Heat?

Radiation is the process of transmitting heat from one body to another through an intervening distance without heating the air between them.

35. What is Conduction of Heat?

Conduction is transmission of heat from one body to another in direct touch with it.

36. Do all bodies conduct heat equally well?

No; the best conductors are the metals—silver, copper, tin, steel, lead.

The poorest conductors are hair, wool, straw, wood, liquids and air not in circulation. These are called "non-conductors."

NOTE RELATING TO THE BAROMETER.—The weight of the atmosphere is measured by its pressure on the barometer. This instrument is a slender glass tube about a yard in length, closed at one end, then filled with mercury and reversed, the open end being placed in a cup of the same fluid.

The atmosphere, pressing upon the fluid in the cup, keeps within the tube a column of mercury exactly sufficient to balance its own weight. At the level of the sea this column, measured by a scale attached to the instrument, is about thirty inches in height. The weight of the entire atmosphere, therefore, is equivalent to that of a layer of mercury thirty inches deep, covering the globe, and exerting a pressure of fifteen pounds on every square inch of its surface.

When from any cause the pressure of the air increases, the barometer rises; when it decreases, it falls.

CHAPTER TWO.

COMBUSTION AND FUEL.

37. What is Combustion?

Combustion is the process of chemical union between certain substances, called "combustibles," and the oxygen of the air. This chemical union produces or liberates sensible heat.

38. What are the combustibles in fuels?

(1.) Free or fixed carbon.

(2.) Hydrocarbons, which are chemical combinations of hydrogen and carbon in different ratios.

39. What is Air?

Air is a mechanical mixture of 23 weight units of oxygen and 77 weight units of nitrogen.

40. What are the common products of combustion?

(1.) Carbonic acid, a chemical union of one part of carbon with two parts of oxygen.

(2.) Water vapor, a chemical union of two parts of hydrogen with one part of oxygen.

(3.) Inert gases, like nitrogen; also unassociated oxygen, and various products due to the impurities of the coal.

41. Which combustible burns first?

The hydrocarbons burn first. Upon charging the fire with fuel, the hydrocarbons are distilled off in form of gas, which burns with the oxygen in passing through the furnace and combustion chamber.

42. How does the fixed carbon burn?

The fixed carbon shows itself in the form of coke, after the hydrocarbons have left it.

It unites with oxygen at once, forming either carbonic acid, by complete liberation of all heat stored in the carbon, or carbonic monoxide, a union of one part of carbon with one part of oxygen, by which only about one-third of the stored heat is liberated.

43. What is the theoretical heat value of one pound of combustible?

The heat value of one pound of carbon is 14,500 thermal units, of different hydrocarbons, between 19,000 and 21,000 thermal units, and of hydrogen about 62,000 thermal units.

44. How much air is needed for complete combustion?

One pound of coal needs about twelve pounds of air, but to make sure that all carbon particles find oxygen, about 20 to 24 pounds of air per pound of carbon are supplied.

45. How is the air for combustion supplied?

The air is supplied either by natural funnel draft or by artificial forced draft.

46. What is natural or funnel draft?

Natural or funnel draft draws the air through the ashpit, grate, fuel, combustion chamber and funnel. It results from the difference in density, or weight, between the column of heated air in the furnace and funnel and an equal column of outside air. The outside air weighs more and tries to rush in at the bottom, to replace the heated air inside and re-establish equilibrium.

The higher the stack, the stronger the draft and the greater the quantity of air drawn through.

47. What is artificial or forced draft?

Artificial or forced draft is supplied by providing an excess of pressure or density under the fuel through blowers.

In this case, the height of the funnel is of no particular consequence.

48. What are the important factors in the regulation of combustion?

The draft is the most important factor; the kind and quality of the fuel is of secondary influence.

49. What are the relations between the draft and the rate of combustion?

The stronger the draft, the greater the consumption of fuel.

50. How is Combustion measured?

Combustion is measured by the rate at which the fuel is consumed per hour on one square foot of grate.

51. What are the normal rates of combustion in marine boilers?

Rate of natural draft = 10 to 20 pounds of coal.
Rate of forced draft = 20 to 50 pounds of coal.

52. How is the combustion affected by the arrangement of the air supply?

To realize complete combustion, the air must be brought into direct contact with the fuel and the developing gases.

53. How is this necessary contact realized?

By supplying air below and above the fire.

54. Upon what depends the effect of the air supply below the fire?

The effect of the air supply below the fire depends partly upon the thickness of the bed of coal, partly upon the kind of coal, and partly upon the impurities contained in the coal.

55. Why is air above the fire desirable?

(1.) To give the hydrocarbons opportunity to quickly and thoroughly intermingle with air containing the normal amount of oxygen. If there is not oxygen enough, some hydrocarbons may pass off unburned, while some parts may burn only the hydrogen, letting the carbon pass off as soot or smoke.

(2.) If carbon monoxide should have been formed in the combustion of the fixed carbon, the air above the fire would burn this into carbonic acid and liberate thereby a large additional amount of heat.

56. Why is a high temperature desirable for complete combustion?

A high temperature of the fire is highly desirable, because the hydrocarbons or their parts are then more quickly united with oxygen and the formation of soot is less.

The fixed carbon also is more completely united with oxygen and less carbon-monoxide is formed.

57. What are Smoke and Soot?

Smoke and soot are unoxydized carbon particles and their presence is a sign of incomplete combustion.

58. What helps to make combustion complete?

A high furnace and large combustion chamber give the gases and the air time for thorough intermingling and burning, besides keeping the hot gases more out of contact with the cooling walls.

With some water-tube boilers the furnaces are set out with fire-brick, a material that conducts heat badly, thus tending to maintain a high temperature and aiding combustion.

59. What are the most important fuels?

(1.) Coal.
(2.) Wood.
(3.) Oil.

60. What are the principal kinds of coal used?

(1.) Anthracite, or hard, coal.

(2.) Bituminous, or soft, coal.

61. What are their characteristics?

Hard coal has about 86 to 90 per cent. of fixed carbon and about 2 to 8 per cent. of hydrocarbons.

Soft coal has about 40 to 74 per cent. of carbon and 16 to 50 or more per cent. of hydrocarbons.

There are also intermediate grades used known as semi-anthracite and semi-bituminous coal that vary in their percentage of hydrocarbons between 8 and 16.

62. What is the average heating value of coal?

The average heating value of one pound of coal may be placed at between 12,000 and 15,000 heat units.

63. What other substances are found in coal?

Sulphur appears in amounts up to 3 per cent., but usually only ½ to 1 per cent.

Ashes are the incombustible substances that may be found in amounts varying from 2 to 12 per cent. in the different kinds of coal.

64. How do these impurities affect the value of coal as a fuel?

Mineral combination of sulphur and iron affects the keeping qualities of some coals. In wet coal particularly it generates heat and sets up a slow oxidation that decreases the heating value of the fuel. Ashes and mineral substances may form clinker by fusing together and obstructing the passage of the air through the fire.

65. How is coal measured?

Coal is usually measured by weight in pounds or tons. For

stowage purposes between 42 and 44 cubic feet per ton of 2,240 lbs. are generally allowed.

66. What are the characteristics of wood as fuel?

Wood contains, on the average, about 50 per cent. of carbon, some 40 per cent. of oxygen, some hydrogen and about 1 per cent. of ashes.

67. What is the average heating value of wood?

Wood has to be dry to obtain full heating value, and produces, on an average, about 6,000 to 8,000 heat units per pound.

68. What are the woods most frequently used for fuel?

Oak, beech, hickory, the different pines and firs.

69. What are the relative fuel values of coal and wood?

One pound of coal would be equivalent to about 2 or 2½ pounds of wood.

70. What are the characteristics of oil as fuel?

Oil for fuel purposes contains about 86 per cent. of carbon, 13 per cent. of hydrogen and one per cent. of oxygen.

71. What is the average heating value of oil?

The average heating value of one pound of oil is between 20,000 and 22,000 heat units.

72. What is the relative value of coal and oil?

Three pounds of coal would be equivalent, in heating value, to about two pounds of oil.

73. What factors decide about the choice of the fuel?

Besides the consideration of the heating value are the commercial ones of price, ease of obtainance, stowage space required and safety of handling.

Coal seems to be the best all-around fuel with high heating

value and fairly low price. It is everywhere easily obtained; has small bulk in proportion to its heat value, and is safe to handle.

Wood has the disadvantages of limited supply and of great bulk in comparison to its heating value. It finds favor where coal is high in price and transportation is easy.

Oil presents disadvantages in point of limited quantity and certain dangers involved in storing and using it. It is used in regions where coal is high in price and transportation difficult.

CHAPTER THREE.

STEAM AND ITS PROPERTIES.

74. What is Steam?

Steam is water vapor.

75. How is steam produced?

By heating water until it evaporates.

76. At what temperature does this evaporation occur?

Under the normal atmospheric pressure of 14.7 pounds pe square inch, it occurs at 212 degrees Fahrenheit.

77. How many heat units are needed to make one poun of steam from one pound of water at 32° Fahren heit?

(1.) Sensible heat to raise the water from 32° to 212°; equivalent to ...	180.9 unit
(2.) Latent heat to change the liquid state to the gaseous; equivalent to ...	894.0 unit
(3.) Latent heat to overcome the resistance of the atmospheric pressure; equivalent to ..	71.7 unit
A total of ...	1,146.6 unit

78. What volume would the steam, obtained from on cubic foot of water, occupy at the atmospheric press ure?

The steam would occupy 1,646 cubic feet.

79. What does steam do, if cooled?

It condenses partially, or totally, into water.

NOTE.—In Part Twelve (pages 813 to 832) will be found additional matter on *Stea* including a condensation of ***Marks and Davis'*** steam tables.

80. What is understood by atmospheric pressure?

Atmospheric pressure results from the weight of the air above the surface of the earth; it is expressed by the weight of a column of air above a surface of one square inch, and amounts to 14.7 pounds on this square inch.

81. What is Vacuum?

Vacuum is the absence of the weight of the air column or the absence of pressure.

82. What is Gauge Pressure?

Gauge pressure is the pressure over and above the 14.7 pounds of atmospheric pressure.

83. What is Absolute Pressure?

Absolute pressure is the total pressure above the vacuum. It is, therefore, equal to the sum of gauge pressure and atmospheric pressure.

84. How does the pressure affect the point of evaporation?

Increased pressure raises the point of evaporation; decreased pressure lowers it.

Water thus boils under a vacuum below 212 degrees Fahrenheit, while under a higher than atmospheric pressure a higher temperature than 212 degrees is required.

85. How does pressure affect the volume?

One pound of saturated steam occupies a smaller space at high pressure than at low pressure, but has a greater density.

86. How does temperature affect the pressure?

The pressure of the steam rises, if the temperature of the water and the saturated steam is raised.

A certain temperature of saturated steam produces always the same pressure.

87. By what property does steam do work?

By the pressure it exerts against the surrounding walls, when confined, as in a boiler.

88. What is Saturated Steam?

Saturated steam is steam in direct contact with the water from which it is generated.

It has the same temperature as this water, and the maximum density for that temperature, and the space which it occupies cannot be filled by any more steam. It can, however, contain water in form of spray or mist, and is then called wet saturated steam.

If this moisture is not present, it is called dry saturated steam.

89. What is Superheated Steam?

Superheated steam is steam that has a temperature higher than corresponds to its pressure. Superheated steam is always dry.

90. How would steam act in a space with one movable side?

The steam would try to push the movable side out, or would expand until the pressure on the inside would be the same as on the outside, or until a retaining resistance should be met.

91. What law does the steam approximately follow in this expansion?

Steam follows approximately the law, that the pressure is inversely proportional to the volume. For example, assume a cylinder with the piston at half stroke, to be filled, one-half with steam of 100 pounds per square inch, absolute pressure, and the other half connected with the vacuum of the condenser, then the steam will push the piston to the end of the

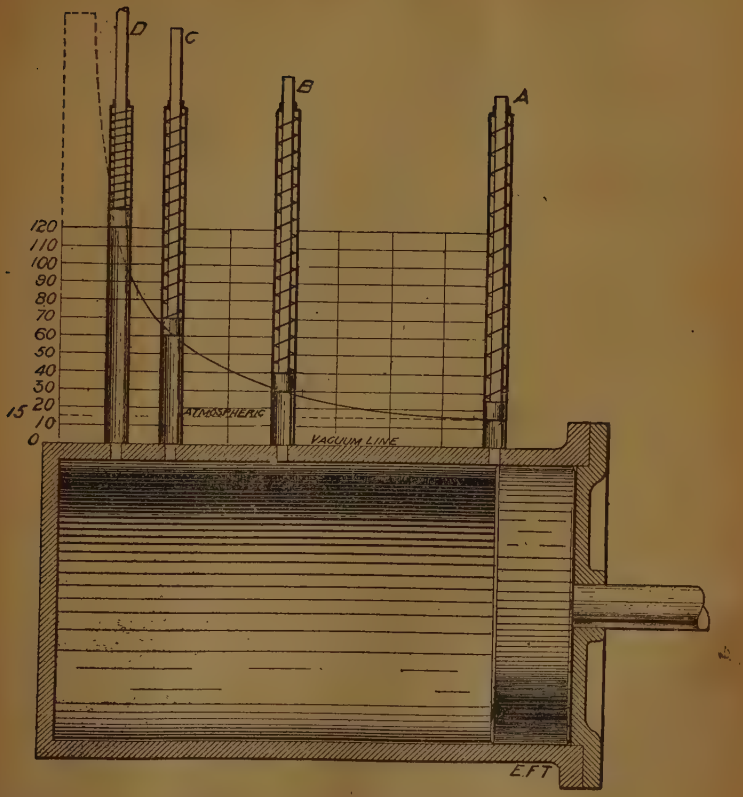


FIG. 32.—Diagrammatic Section of a Cylinder Illustrating the Compression and Expansion of Gases. This cylinder is filled with air at atmospheric pressure which represents a uniform 14.7 pounds to the square inch behind the piston, as shown by the position of the piston in the small cylinder, A. When the piston of the large cylinder is moved through half the length of the stroke, it shows 30 pounds pressure, as shown by the position of the piston in small cylinder, B; when at three-quarters stroke, 60 pounds, as shown by position to the piston, C; when at seven-eighths stroke, 120 pounds, as shown by position to piston, D. At full stroke it would be 240 pounds, the diagram behind the small piston giving the compression curve from 15 to 240.

The cylinder of a steam engine operates on this same principle of varying pressure, and, as shown by indicator cards, as in Fig. 33, the pressure falls regularly from the point of cut-off to the end of the stroke. The "curve of expansion" is, theoretically, the same as the curve passing through the centres of the small pistons, D, C, B, A, in this figure.

stroke, making its own volume twice as large, and reducing its absolute pressure one-half, or to 50 pounds per square inch.

If, for another example, it is assumed that the piston had advanced only one-tenth of its stroke, and, therefore, only one-tenth of the volume was filled with steam of 100 pounds per square inch, absolute pressure; then, upon pushing the piston to the end position, the volume would be increased tenfold, while the pressure would be decreased tenfold down to 10 pounds per square inch, absolute pressure.

92. How much steam would be used in these two cases?

Assuming that in both cases the cylinder has a cross sectional area of 1,000 square inches and a piston stroke of 30 inches, the result is for the first case:

$$1{,}000 \times 15 = 15{,}000 \text{ cubic inches of steam.}$$

For the second case:

$$1{,}000 \times 3 = 3{,}000 \text{ cubic inches of steam.}$$

93. How can the work of the steam, during one stroke, be determined?

As seen before, work is force multiplied by distance, or, in this case, pressure in pounds multiplied by stroke in feet, giving foot-pounds of work.

As the pressure changes during expansion, it will be necessary to subdivide the stroke into a large number of small parts.

This allows the pressure to be considered constant during each of these small parts of the stroke; the work during each of them is found as a product of this constant, or mean, pressure and the length of each part.

Finally, all the products have to be combined into one sum total.

94. How can this sum total of work be shown graphically?

By the so-called indicator diagram as shown on Fig. 33, the area of which represents the work.

95. What is the mean pressure?

The mean pressure is an average of all the varying pressures at all the subdivisions of the stroke, and is used, for convenience, in calculating the total work done by the steam.

96. How is the mean pressure found?

By dividing the length of the diagram into a number of equal parts—in Fig 33, 10 parts—adding the mean pressures of each tenth part and dividing the sum by 10.

It is for the first case = 84.782 pounds.

It is for the second case = 33.789 pounds.

97. How much work does the steam perform in the cases A and B, Fig. 33?

A. The mean pressure per square inch is 84.782 pounds, which has to be multiplied by 1,000, the number of square inches in the area of the piston, giving 84,782 pounds total pressure.

This total pressure multiplied by 2.5 feet = 30 inches travel, gives 211,955 foot-pounds of work.

B. The mean pressure, 33.789 pounds per square inch, multiplied by 1,000 gives 33,789 pounds total pressure, which, multiplied by 2.5 feet, gives 84,472.5 foot-pounds of work.

98. How much more work is done in A than in B?

211,955 foot-pounds divided by 84,472.5 foot-pounds gives 2.51 times more work done in A than in B.

99. How much more steam was put into A than into B?

A was filled one-half, while B was filled one-tenth. Therefore, A had 5 times more steam than B. In other words, in

FIG. 33.—Two Theoretical Indicator Cards, the first showing cut-off at one-half stroke, the second at one-tenth stroke. Other particulars, length of stroke and initial pressure (100 lbs.), being the same, diagram A shows a final pressure of 50 lbs., diagram B of about 11.11 lbs. Consequently the mean effective pressure (M. E. P.), calculated by ordinates, as explained in Fig. 34, is 84.782 lbs. for A, and 33.789 lbs. for B.

order to do 2.51 times more work, A had to be filled with 5 times more steam than B.

100. Which case is, therefore, the most economical, A or B?

B is the most economical, and from this fact it is concluded that THE GREATER THE EXPANSION THE GREATER, THEORETICALLY, THE ECONOMY.

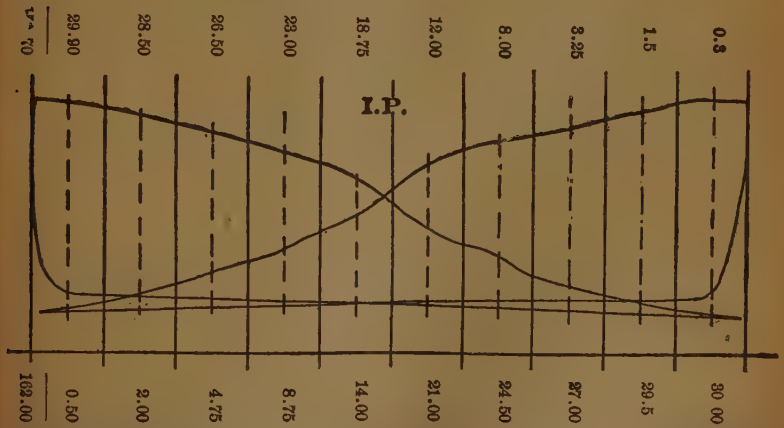


FIG. 34. -Average Indicator Card from the Intermediate Cylinder of a Triple-expansion Engine, giving figures for both forward and backward strokes. The diagrams shown in Fig. 33 are for only one stroke. This card is also ruled, as shown by the full lines, into ten equal sections. Through the centre of each section is ruled a dotted line, on which by reference to the number and tension of the spring used in the indicator the pressure at those points may be found by measuring on the dotted line between the base line and the expansion curve. The numbers indicating these several pressures, in pounds, are then added together, the results being 151.70 for the right-hand stroke, and 162.00 for the left-hand stroke. Dividing by 10, as in the case of Fig. 33 we have 15.17 pounds, M. E. P., for the one, and 16.2 pounds, M. E. P., for the other. Adding these two results, we have 31.370, which, divided by 2, gives 15.685 pounds, M. E. P. For a card showing both strokes the M. E. P. may also be found, thus: $162 + 151.7 = 313.7$, which divided by 20 gives 15.685, M. E. P.

101. What practical limit has this law?

(1.) To do a certain amount of work with very high expansion would require very large and, therefore, costly cylinders and engines.

(2.) With high expansion the temperature changes in the

cylinder are great, which causes large condensation and consequent loss of steam and work.

102. How may this harmful condensation be partially avoided?

(1.) By arranging the expansion in several steps, as is done in multiple cylinder engines.

(2.) By superheating the steam, and thus providing an excess of heat that can be used for heating the cylinder walls.

103. What is otherwise desirable for economy?

To begin the expansion with a pressure as high as possible.

CHAPTER FOUR.

MECHANICS AND ECONOMICS OF THE MARINE ENGINE.

104. What is the path of the piston under the pressure of the steam ?

The straight line that the piston travels over in its reciprocations, or backward or forward movements.

105. How is this reciprocating movement used for the propulsion of ships ?

It is transformed into the rotary movements of the shaft and propeller.

106. How is this transformation accomplished ?

By swinging, connecting rods joined at one end to the firmly guided piston rod and at the other end to a revolving crank.

107. Does the crank transmit a uniform turning effort ?

No ; at the top and bottom positions of the crank it transmits no turning effort at all.

108. How is this turning effort employed for the propulsion of the ship ?

The turning effort is transmitted by shafting to the propellers that drive the ship.

109. How do the propellers drive the ship ?

The revolving motion of the propellers is converted into the straight line travel of the ship.

(1.) In paddle wheels, by transmitting pressure to the water in the line of a tangent through the blades on the immersed arc of the wheel.

(2.) In screw-propellers, by transmitting pressure to the water in the line of the axis of the wheel through the twist of the blades.

110. Is the work from the steam all applied to the task of propelling the ship?

No; there are numerous losses between the two ends of the chain, known in general as "mechanical losses."

111. Is all the heat of the fuel utilized in the work done by the steam?

No; there are here also numerous and great losses, known as "heat losses."

112. What are the heat losses in the boiler?

(1.) Incomplete combustion and smoke.
(2.) Heat in funnel gases.
(3.) Heat radiated from the boiler body.

113. What is the percentage of loss in the process of transmitting the heat of the fuel to the generated steam?

From 25 to 30 per cent. is the average loss in good installations, while it is even larger in poor ones.

114. How is the performance of the boiler as a steam generator expressed?

It is expressed by the number of pounds of water evaporated to steam by one pound of coal.

115. How great is this proportion for good practice?

From 9 to 10 pounds of steam should be produced by one pound of good coal.

116. What are the heat losses in the engine?

(1.) Radiation and conduction from pipes and cylinders.
(2.) Condensation on the surfaces of the cylinders.
(3.) Sensible and latent heat carried off in the condensing

water, due to the fact that only the heat between the extreme temperatures of the steam in the engine can be be turned into work.

117. What is the percentage of loss in turning the heat of the steam into work ?

This loss is very large, being for average good practice from 78 to 84 per cent.; leaving only from 16 to 22 per cent. of the heat of the steam actually turned into work.

118. How is the performance of the engine as a generator of work expressed ?

It is expressed by the number of pounds of steam per hour that is required to produce one horse-power, or 33,000 foot-pounds per minute.

119. How great is this number for good practice ?

From 14 to 20 pounds of steam per hour are needed for one indicated horse-power.

120. How great is the percentage of loss in turning the heat capacity of the fuel into work ?

From 84 to 90 per cent. of the heat of the fuel is lost and only 11 to 16 per cent. is turned into work, with good average boilers and engines.

121. What is the equivalent of one horse-power in heat units per hour ?

One horse-power equals 2,546 heat units per hour.

122. How many horse-power per hour could one pound of coal produce, theoretically ?

If we assume 13,500 heat units per pound of coal, it would furnish 5.3 horse-power for one hour.

123. How many horse-power per hour could one pound of coal produce, practically, with good modern boilers and engines of 11 to 16 per cent. efficiency?

One pound of coal will furnish from 0.583 to 0.838 horse-power for one hour. One horse-power will require 1.2 to 1.8 pounds of coal per hour.

124. What are the mechanical losses?

(1.) Friction in the engine and shafting.
(2.) Resistance and friction of the propeller.

125. How great is the percentage of these two losses?

From 42 to 50 per cent. of the total indicated horse-power is lost, leaving from 50 to 58 per cent. for the useful thrust to overcome the resistance of the ship.

126. What are the principal components of the resistance of the ship?

(1.) Skin-friction resistance.
(2.) Wave-making resistance.

127. To what is the resistance of the ship referred?

(1.) To the square feet of wetted surface.
(2.) To the two-third power of the tons of displacement.

128. What ratio can be established between resistance and speed?

For approximate results, resistance varies as the third power of the speed.

For example, if 1,000 horse-power are required for a speed of 10 knots, then 8,000 horse-power are required for 20 knots; or it requires eight times the horse-power to double the speed.

129. How does this affect the coal consumption?

It will require eight times more coal to double the speed.

130. How will this affect the steaming radius of ships?

The steaming radius of a ship with a bunker capacity of 500 tons and a coal consumption of 5 tons per hour at 10 knots speed would be :

10 knots : $\frac{500}{5}$ — { 100 hours × 10 knots — 1,000 knots total voyage.

20 knots : $\frac{500}{5 \times 8}$ — { 12.5 hours × 20 knots — 250 knots total voyage.

131. How do engineers make use of this law ?

They make use of this law when the coal on hand would not last to the end of the voyage at the average rate of speed and coal consumption. By reducing the speed and the coal consumption per hour they are enabled to cover a greater total distance, with a given amount of coal on hand.

FIG. 35.—The First Transatlantic Steamship, the "Savannah" (1818). On her first voyage this ship crossed the ocean in twenty-six days, traveling for eighteen days under steam. The immediate result was to demonstrate the possibility of transoceanic steam travel.

PART TWO.

THE STEAM BOILER AND STEAM GENERATION.

CHAPTER FIVE—THE CHARACTERISTICS OF STEAM BOILERS.

CHAPTER SIX—TYPES OF STEAM BOILERS.

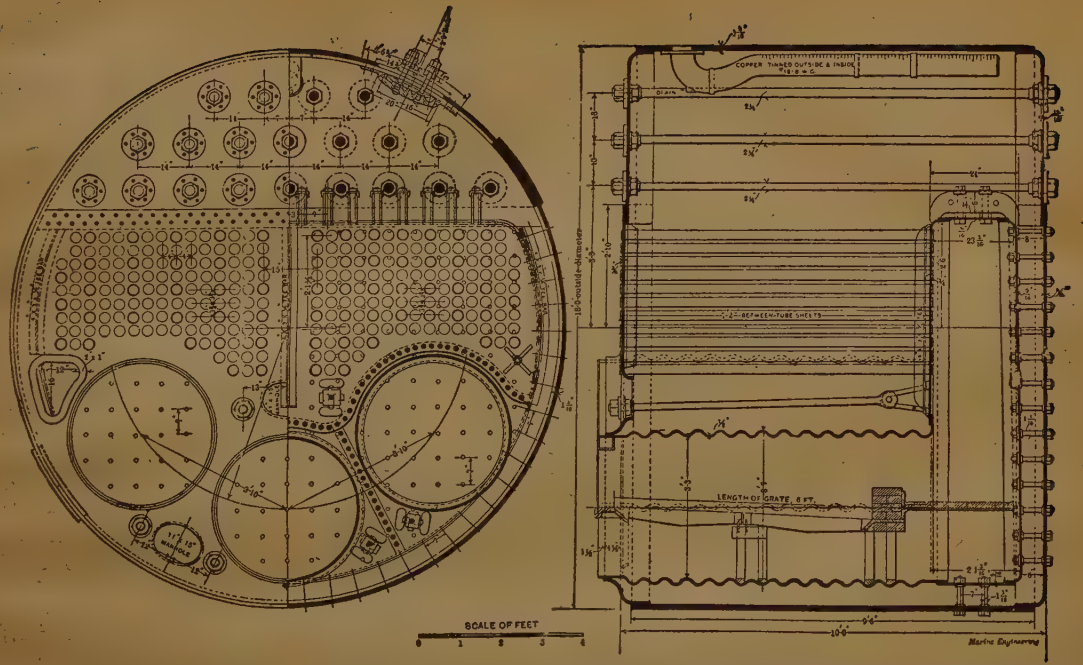
CHAPTER SEVEN—DETAILS OF CONSTRUCTION: FIRE-TUBE BOILERS.

CHAPTER EIGHT—DETAILS OF CONSTRUCTION: WATER-TUBE BOILERS.

CHAPTER NINE—OPERATIVE DETAILS OF MARINE BOILERS: FUEL AND FIRE GASES.

CHAPTER TEN—OPERATIVE STEAM APPLIANCES OF MARINE BOILERS.

CHAPTER ELEVEN—OPERATIVE WATER APPLIANCES OF MARINE BOILERS.



Sections of a modern high pressure Scotch boiler with three corrugated cylindrical furnaces, showing construction and dimensions of parts. This type of boiler is described in Sections 170-173.

CHAPTER FIVE.

THE CHARACTERISTICS OF STEAM BOILERS.

132. What is the prime function of a boiler?

The prime function of a boiler is to transfer heat from the gases of combustion to water, and thereby generate steam.

133. What means is provided for this transfer of heat?

Heating surface.

134. What are the requisite qualities of this heating surface?

The heating surface must absorb the heat of the burning gases as completely as possible, while keeping the water and steam from coming into direct contact with the fire.

135. What qualities should the material of a boiler heating surface embody?

(1.) The material of the heating surface should be a good conductor.

(2.) It should have ample strength to retain the steam under pressure, even if heated to a high temperature.

136. What material is best suited to this purpose?

Iron, in general, or in the special form of steel, as it is a fairly good conductor of heat and has great strength, besides being obtainable in unlimited quantities at a low price.

137. What is the most convenient form in which to arrange the heating surface of a boiler?

The tubular form is most convenient, as having great strength and lightness of weight, while easily manufactured.

138. What other important parts are contained in boilers?

(1.) A shell and heads, which are not heating surfaces, are required to complete a tight receptacle for holding the steam and water.

(2.) Since the combustion of the fuel takes place around and within the boiler, shell space must be provided for the combustion, and also for the passage of the gases over the whole heating surface.

139. How long should the gases be in contact with the heating surface?

The gases should be in touch with the heating surface until they become cooled to such an extent that active and quick transmission of heat stops. This is assumed to occur when the gases have reached a temperature of from 600 to 800 degrees Fahrenheit.

140. How extensive should the heating surface be?

The heating surface should be large enough to effectually reduce the temperature of all gases, the size in square feet being regulated according to the number of pounds of fuel from which the gases are developed.

141. Where are these gases developed from the fuel?

On the grate.

142. What is the function of the grate?

The duty of the grate is to spread the fuel so that the air has easy access to it, uniformly, all over, and effects thereby a combustion as complete and as regular as possible.

143. What should be the dimensions of the grate to effect the spreading of the fuel to best advantage?

The grate should be rather wide than deep, as this will allow the fireman to spread the fuel in more uniform thickness, and keep it in better condition for complete combustion

144. What determines the number of pounds of fuel that can be burned?

The amount of fuel consumed depends upon the area of the grate and the draft.

145. How are the heating surface and the grate area measured?

The heating surface and the grate area are expressed in square feet.

146. What is the ratio between grate area and heating surface?

The ratio of heating surface to grate area varies usually between 30 to 1 and 40 to 1, because it has been found that the heat of the gases produced from the fuel on one square foot of grate area can be effectively and economically absorbed by from 30 to 40 square feet of heating surface.

147. What are the limits of differing ratios in draft?

With forced or strong draft the upper limit of 40 to 1, or even as high as 50 to 1, is chosen, as the volume of the gases of combustion per square foot of grate increases. For natural draft the lower limit of 30 to 1, or even as low as 27 or 28 to 1, is employed.

148. What part of the heating surface is most effective in the transmission of heat?

The part of the heating surface nearest to the fire is always the most effective, as there the differences in temperature of gases and water are the greatest, and, therefore, the absorption of heat is the quickest.

149. How is the transmission of heat by the heating surface measured?

By the number of pounds of water evaporated per square foot of heating surface per hour.

150. What are average rates of evaporation per square foot of heating surface?

For natural draft about three pounds per hour. For forced draft up to seven or more pounds of water per square foot of heating surface per hour.

151. How is the efficiency of evaporation affected by the different rates?

The efficiency of evaporation is higher at low rates, because the heat is more completely absorbed.

But, in practice, it is not found profitable to go below average rates of evaporation, as a boiler, to produce a certain amount of steam, would have to be much larger and more expensive, if worked with low rates, than if worked with high rates of evaporation per square foot of heating surface.

152. How should the gas passages be arranged?

The gas passages should be so arranged that the whole heating surface can readily absorb the heat of the gases.

153. In relation to what do we calculate the area of the gas passages?

The area of the passages is placed in relation to the area of the grate; the ratio between them is usually one square foot of passage for a total of from seven to nine square feet of grate.

154. What is the ratio of the air space area of the grate to the area of the total grate and to the area of passages?

The area of the air space is from one-third to one-half of the total grate area, and one square foot of passage is usually provided for every 3 to 3.5 square feet of air space of the grate.

155. Is the area of the gas passages uniform throughout its course?

No; the area of the passages decreases, usually toward the

funnel, making the gases travel faster when their heat excess is smaller.

156. What is the water-space of the boiler ?

The water-space of the boiler is that part of its interior that is nearest to the heating surface.

157. How should the water-space be arranged ?

The water-space should be arranged so that the steam evaporated from the heating surface can, by rapid and undisturbed circulation, be replaced by water in the liquid state.

158. Why is this rapid circulation needed in all boilers ?

This rapid circulation of the water is needed to prevent over-heating of the heating surface ; since water should be kept in contact with the heating surface in order to absorb sufficient heat to avoid dangerous temperatures.

159. What is steam-space ?

The steam-space is that part of the interior of the boiler that is removed from the heating surface and above the water-space, in order to allow for accumulation storage space for the steam.

160. What is the water-surface ?

The water-surface is the area of contact between water and steam. It provides for the escape of the steam-bubbles from the water.

161. What may result from contraction of the water-surface in relation to the heating surface ?

A contraction of the water-surface may, on account of the great violence with which the steam particles break through the water-surface, produce priming. Priming is the carrying of small water particles into the steam, making it wet steam, that is liable to deposit this water in dangerous quantities in pipes or cylinders.

162. How high should be the water level in a boiler?

The water should cover all fire-touched heating surface, at least several inches deep, giving due consideration to inclined positions in which boilers may be placed on board of ships.

163. What auxiliaries may be added to the heating surface for better use of the heat of the gases?

(1.) Super-heaters, in which the steam is heated to higher temperatures than in the boiler.

(2.) Air-heaters that heat the air for combustion.

(3.) Feed heaters that heat the feed water before it enters the boiler.

164. What are the principal reasons for sub-division of steam generating capacity?

The steam generating capacity may be concentrated in a single boiler or divided into two or more units. The single boiler possesses the advantage of simplicity of use, as there is only one steam delivery and one water supply to watch.

As a single boiler is usually of fairly large dimensions, it has greater steadiness of steaming, as well as, relatively, better economy. There is, however, in case of accident, a complete stoppage of steam delivery, that might leave a ship entirely helpless.

In single units the width of grate may be necessarily limited, and by making up in length the efficiency of firing may be reduced.

A sub-division into several boilers introduces a greater complication, but gives greater safety, as well as sometimes greater handiness. Frequently a small boiler, called a "donkey boiler," is installed to furnish steam for port use, to drive winches, pumps, turning engine, etc.

165. How does the position of the boilers affect the convenience and safety of handling?

The boilers may be placed low in the hold, as in most sea-going ships, or above the waterline, as in many river and bay steamers. The latter position affords a certain convenience in discharging ashes and handling coal, while the former is the safer for sea-going ships.

In many steamers care must be taken that the heat of the boilers will not prove injurious to the ship or cargo.

RULE II, 11.—*Externally heated boilers* shall have a clear space between the boiler and the woodwork of not less than 6 inches at the sides and 4 inches at the top.

Internally heated boilers shall have a clear space between the boiler and the woodwork of not less than 4 inches at the sides and 4 inches at the top.

All woodwork or other ignitable substance approaching within 12 inches of the boiler or smoke stack (unless such boiler or smoke stack is covered with good non-conducting material) shall be suitably sheathed with metal over non-combustible material, and it shall be the duty of the inspectors to see that all woodwork or other ignitable substance in or around the fireroom is properly protected by metal or asbestos sheathing.

All boilers hereafter placed in wooden steamers shall have a clear space of at least 8 inches between the underside of the cylindrical shell and the floor or keelson; and on all other steamers the boilers shall be so placed as to permit of proper inspection of the underside thereof.

All water-tube or coil boilers shall have a clear space of not less than 4 inches between the back end of boiler and bulkhead. All other boilers shall have a clear space of not less than 2 feet between the back end of boiler and bulkhead. (Secs. 4418, 4470, R. S.)

CHAPTER SIX.

TYPES OF STEAM BOILERS.

166. What are the principal types of boilers?

(1.) Fire-tube boilers.

(2.) Water-tube boilers.

167. What is the principal distinction between them?

Fire-tube boilers have the hot gases inside of the tubes Water-tube boilers have the water inside of the tubes.

168. What other division of boilers may be made?

Boilers may be classified according to the pressure they ar intended to carry.

(1.) Low pressure boilers, with pressures up to about 5 lbs. per square inch are much used in connection with bean or single cylinder engines.

(2.) High pressure boilers, with pressures from 150 to 30 pounds per square inch, are used in connection with tripl and quadruple expansion engines.

169. What are the common forms of the fire-tube boiler

The common forms of fire-tube boiler are:

(1.) Scotch boiler.

(2.) Vertical boiler.

(3.) Locomotive boiler.

(4.) Leg, or flue and return tube, boiler.

(5.) Western river boiler.

170. What are the distinctive features of the Scotc boiler?

The Scotch boiler is essentially a boiler for high pressur

and has, for this reason, most of the important members in cylindrical shape.

They are all arranged horizontally. The gases pass to the back and are returned to the front for discharge.

171. What are the important parts of the Scotch boiler?

(1.) Cylindrical shell, which encloses the steam and water-space.

(2.) 1, 2, 3 or 4 cylindrical furnaces that provide room for the grate.

The grate divides the furnaces into the space for the gases above and into the ash-pit below the grate.

(3.) Cylindrical tubes in large number, above and parallel to the furnaces. These constitute the bulk of the heating surface and lead the gases to the uptake at the front of the boiler.

(4.) 1, 2 or 3 combustion chambers, or boxes for the combustion of the gases. They form the passages for the gases from the rear end of the furnaces to the tubes.

They have flat tops, backs and tube plates and sides that require staying to resist the pressure of the steam.

(5.) Heads to close the ends of the cylindrical shell. These require staying to resist the steam pressure provided, partly by special bolts, partly by the tubes.

(6.) Uptake and funnel to carry off the burnt gases.

172. In what special forms is the Scotch boiler constructed?

The Scotch boiler may be single ended or double ended. In the latter case it has combustion chambers common to either end, or else separate.

As a usual thing, Scotch boilers are large in diameter to accommodate furnaces and return tubes all in one end; for special uses, as where headroom is limited, a form known as the gunboat boiler is built.

It contains only the furnaces in the front, the combustion chamber at the centre, and the tubes at the rear of the boiler. The gases, therefore, have a straight passage through a cylinder of small diameter and great length.

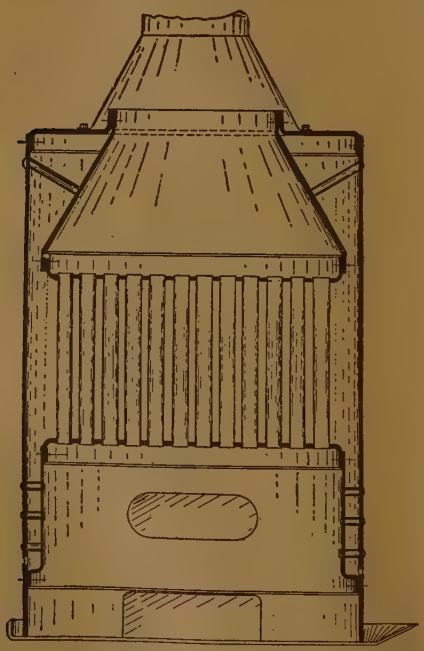


FIG. 36.—Submerged Tube Vertical Boiler. As may be understood from this cut, the steam space is above the top of the fire flues, surrounding the smoke vent, above the upper tube-sheet. This forms the submerging chamber.

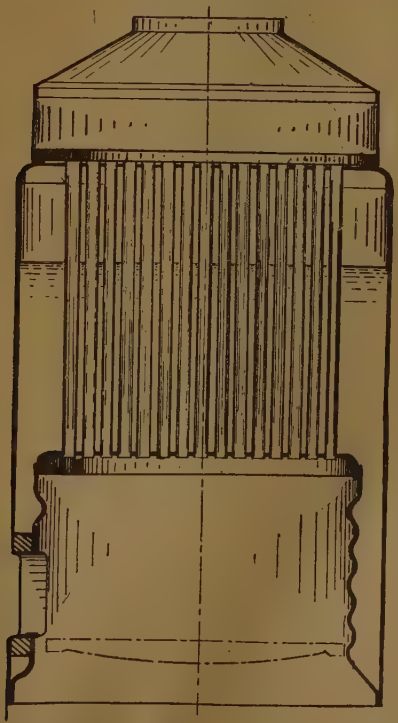
173. What are the distinctive features of the vertical boiler?

The vertical boiler has nearly all its members in cylindrical shape, and arranged vertically. The gases pass directly into the stack.

174. What are the principal parts of the vertical boiler?

(1.) The cylindrical shell, which encloses the steam and water-space.

(2.) The furnace and combustion chamber, which is divided



IG. 37.—Flush Tube Vertical Boiler. Unlike the type of generator shown in Fig. 36, the steam and water space in this boiler is below the level of the upper tube-sheet into which the fire-tubes are expanded.

by the grate into the fire and gas chamber and the ash-pit below.

The cylindrical furnace is flanged out, at the bottom, until t meets the shell, dispensing, in this way, with the lower ead.

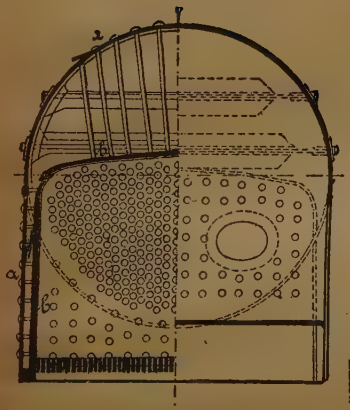


FIG. 38.

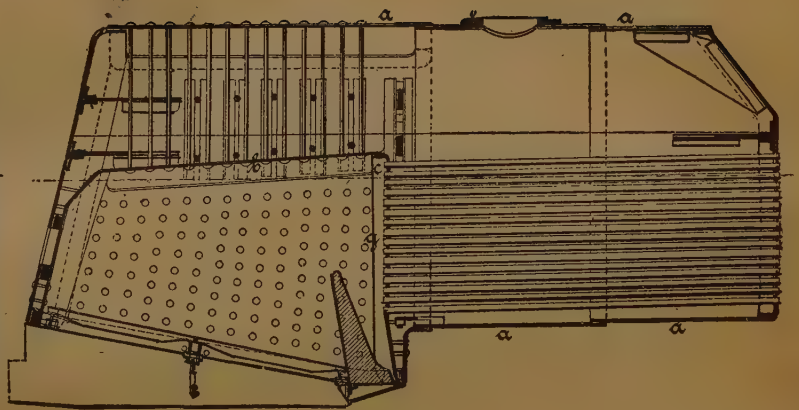


FIG. 39.

FIG. 38.—Half Front Section of One Pattern of Locomotive Type of Marine Boiler. The outside shell of the steam and water space is designated by *a*, the shell of the furnace by *b*, the water-leg being in the space between.

FIG. 39.—Longitudinal Section of One Pattern of the Locomotive Type of Marine Boiler.

In one side it flanges to the shell, for the fitting of the furnace door.

The top is flat for the reception of the tubes.

(3.) Cylindrical tubes, in large number, which connect either with the top head of the shell or with the bottom of a submerging chamber that keeps the upper ends of the tubes always below the water level.

(4.) The top head that limits the steam-space.

It requires staying against the steam pressure, where the tubes, or submerging chamber, do not fill this office.

(5.) The submerging chamber, usually in form of a cone, to lead the gases to the stack directly above.

175. What are the distinctive features of the locomotive boiler?

The locomotive boiler is of cylindrical form through most of the length of the shell, and in the tubes, while the furnace and forward portion of the shell are constructed in box form. The tubes are arranged horizontally and the gases pass directly from the furnace in the front through the tubes to the rear of the boiler and to the smokestack.

176. What are the principal parts of the locomotive boiler?

(1.) The shell, consisting of two parts, a cylindrical one in wake of the tubes and the front part with rounded top on a box-shaped lower half.

(2.) The furnace and combustion chamber, with the grate in the open bottom, opening through the water-space at the front, with the furnace door.

It is separated from the shell and the heads by water-spaces.

The sides and the sometimes flat, sometimes rounded, top require staying to a large extent.

The sides, at the bottom, are sometimes flanged to the shell

Fig. 40.—Longitudinal Section of the Leg Boiler, showing the large flues leading from the furnace to the rear of the boiler; the

and heads, and sometimes connected to them by a solid, forged ring of the thickness of the water-space.

(3.) Cylindrical tubes in large number and relatively small diameter, which connect the furnace to the rear head of the shell.

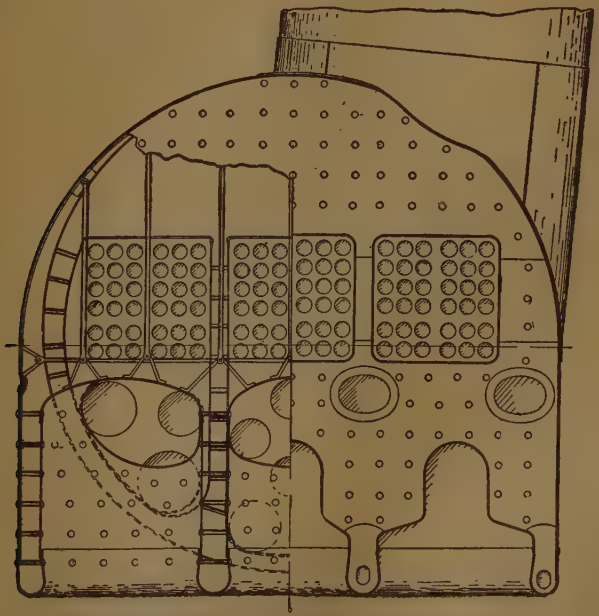


FIG. 41.—Two Plane Sectional Front View of the Leg Boiler, showing the location of the furnaces and the larger and smaller smoke flues.

(4.) Front and back heads to complete water and steam-space; also a sheet, called the throat-sheet, connecting the cylindrical shell at the bottom to the box portion.

177. What are the distinctive features of the leg, or flue and return tube, boiler?

(1.) The leg boiler has cylindrical shape, in that part of the shell containing the flues and tubes, while the one or more furnaces are similar to that in the locomotive boiler.

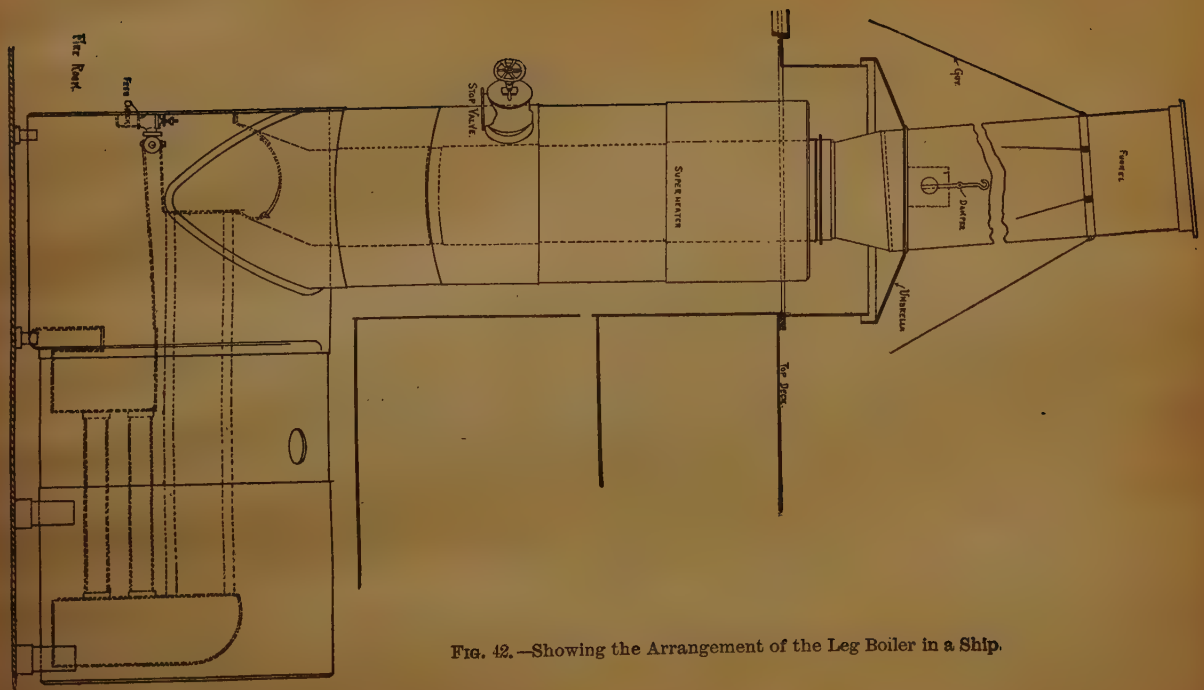


FIG. 42.—Showing the Arrangement of the Leg Boiler in a Ship.

(2.) The one or more combustion chambers are similar to those of the Scotch boiler.

(3.) The flues and tubes are arranged horizontally and the gases pass to the rear, being returned to the front into an uptake chamber, frequently built into the boiler. Around this

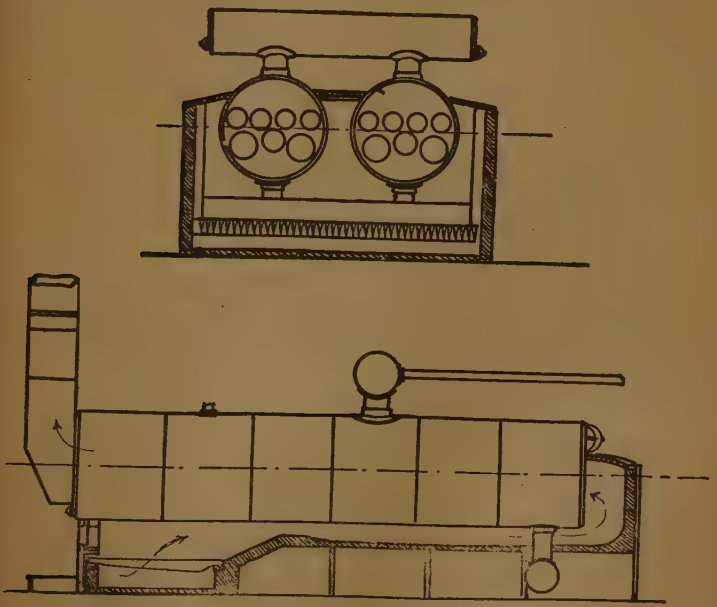


FIG. 45.—Front and Longitudinal Sections of the Western River Boiler, showing steam-drum, steam-pipe and mud-drum.

uptake is often a vertical, cylindrical extension of the steam-space, which acts as a superheater and steam-drier.

178. What are the distinctive features of a Western river boiler?

(1.) The furnace and forward portion of the gas-passages are built of brick, outside of the body of the boiler.

(2.) The cylindrical shell thus acts as heating surface. Th gases are returned from the back through the cylindrical flue to the uptake at the front. The boiler is very simple and ca be used for high pressures.

179. How are water-tube boilers classified ?

Water-tube boilers may be classified in a number of way

(1.) By the size of the tubes, into large and small tub boilers.

(2.) By the form of the tubes, into straight or curved tub boilers.

(3.) By the position of the upper ends, in regard to wate level, into drowned tube, or priming tube, boilers. In th drowned tube variety the tubes are all below the water-leve in the priming-tube variety their upper ends extend above th water-level.

(4.) By the arrangement of the tubes, which may be con nected into groups, with a common steam discharge, or a single tubes.

(5.) By the arrangement of the circulation, as single tube double tube boilers.

(6.) By the manner of fastening the tubes, as screwed expanded tube boilers.

(7.) By the position of the tubes, as vertical or horizonta tube boilers.

180. What are the main parts of water-tube boilers ?

(1.) The steam drum for collecting and delivering the ger erated steam. The lower third of this drum is usually water-space, while the upper two-thirds is the steam-spac Its shape is nearly always cylindrical, with flat or bumpe heads in each end.

(2.) The tubes of the cylindrical section, which compo the heating surface. They connect either directly to the drum or to headers, or chambers, that discharge into the drum.

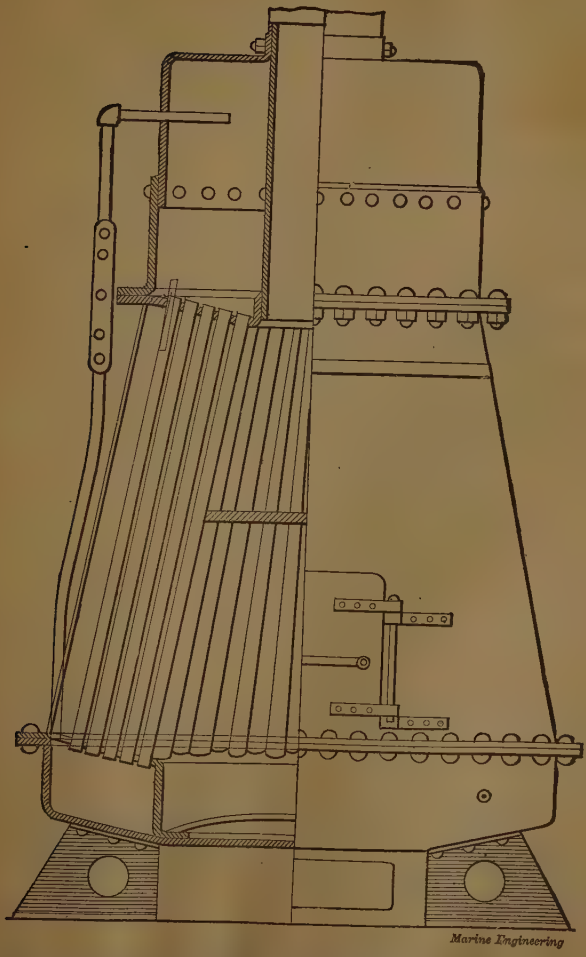


FIG. 44.—Types of Water-tube Boilers, I.—Part Sectional Elevation of the Watson Radial Water-tube Boiler. The steam and water spaces of this boiler, which are, as shown, annular steel drums, are connected by numerous tubes inclined so as to form a truncated cone. A baffle plate is inserted just above the combustion space for the purpose of leading the gases of combustion between the tubes.

(3.) One or more bottom drums that supply the tubes with water. They are frequently cylindrical tubes and receive the lower tube or header ends.

(4.) Down-comers, which are necessary to some forms, while missing in others. They return the water from the top drum to the lower ones, thus completing the continuity of water circulation.

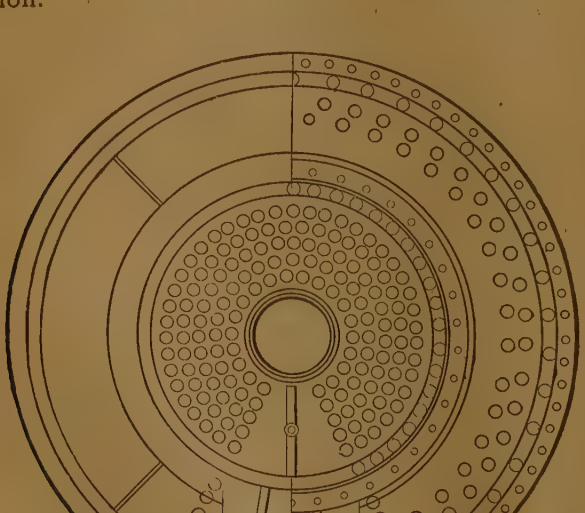


FIG. 45.—Plan View of the Watson Water-tube Boiler, showing connections of tubes to crown-sheet of lower drum and perforated baffle plate hung above the combustion space.

In some forms this return of the water takes place in the chambers, or through some of the tubes.

These constitute the parts that contain the water and steam. The fire and gas chamber, as well as the gas passages, along and over the heating surface to the stack, are formed by casing

and division walls of brick or sheet-iron lined with asbestos, or other insulating material.

These casings should be so constructed as to absorb and radiate as little heat as possible.

181. What are the advantages of the fire-tube boilers?

(1.) Steadiness of steam generation. With their large mass

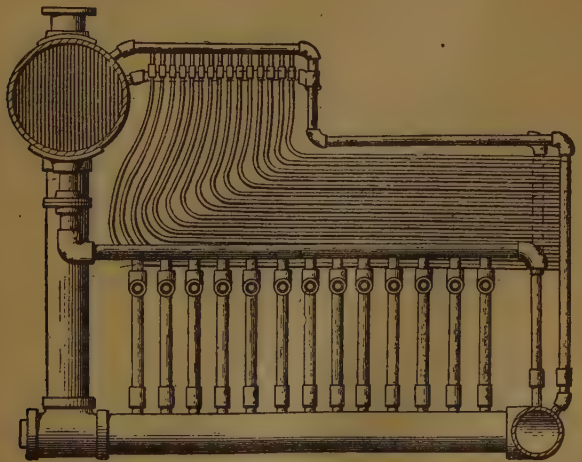


FIG. 46.—Types of Water tube Boilers, II.—Part Sectional Sketch of the Boyer Boiler.

of water, they are not easily affected by differences in the heat transmission or in the steam discharge.

(2.) Steadiness of water-level. With their broad water surface they are not easily affected by differences in the rate of evaporation or in the feed-water supply.

(3.) Relative simplicity. They can be constructed in large units, with a correspondingly limited number of valves, joints and fittings.

(4.) They are comparatively easy to care for.

In some boilers it is possible to clean the heating surface in the tubes or to plug a leaky tube.

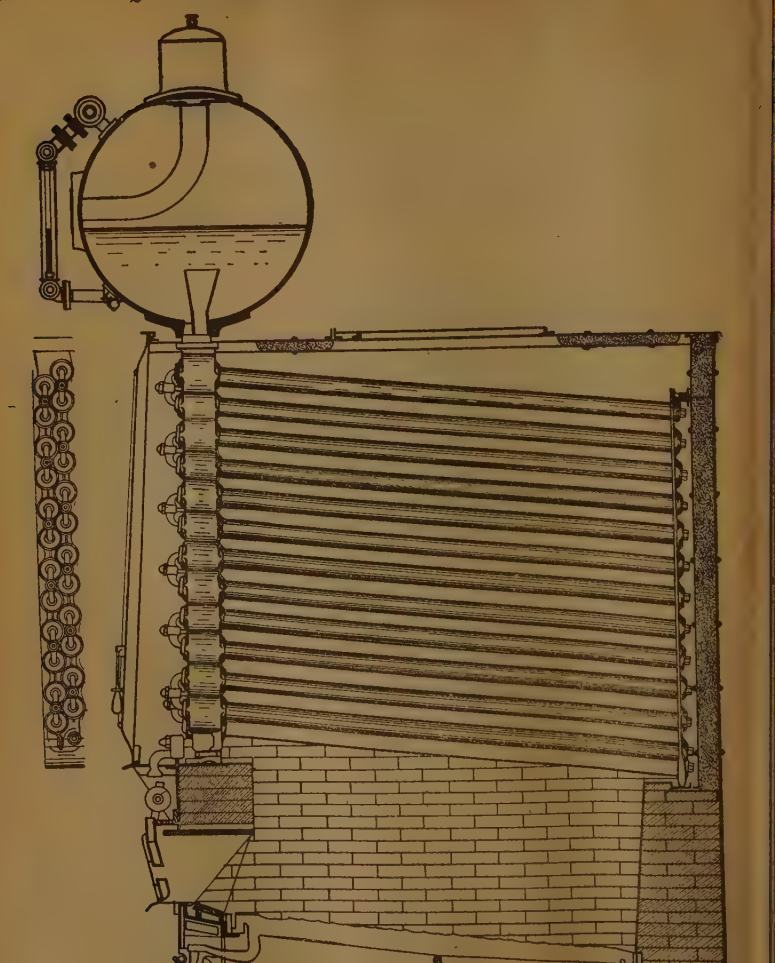


FIG. 47.—Types of Water-tube Boilers, III.—The Niclausse Boiler. Each of the tub
of this boiler, nested, as shown in the left-hand diagram, contains another tube.e

(5.) They possess a certain indifference to salt water feed, if used in urgent cases.

(6.) Some of them can reduce heat loss by radiation to the minimum, as the fire is all inside.

182. What are the disadvantages of fire-tube boilers?

(1.) Weight, which, compared to horse-power delivered, is higher than for the water-tube boiler, particularly with high steam pressures.

FIG. 48.—Detail of Header Connection to Steam Drum in the Niclausse Boiler. As shown in this sketch, the water circulates through the outer tube, entering the drum as shown by the arrows. The down-coming current is through the inner tube.

(2.) Inability to generate steam quickly; since the large body of water must be uniformly heated to prevent straining and leakage in the joints by unequal expansion.

(3.) Inability to stand strong forced draft, as the tube joints in particular are liable to become leaky.

(4.) There is also a great sensitiveness to rapid cooling, as in leaving the fire-doors open, etc., that starts the joints leaking and strains the whole structure of the boiler.

(5.) Great bulk, making it difficult to remove the boiler for repairs, etc., through the hatches of the decks. This is rather

a difficult operation as the boiler must be handled completely riveted together.

(6.) Possibility of disastrous explosions if the steam pressure

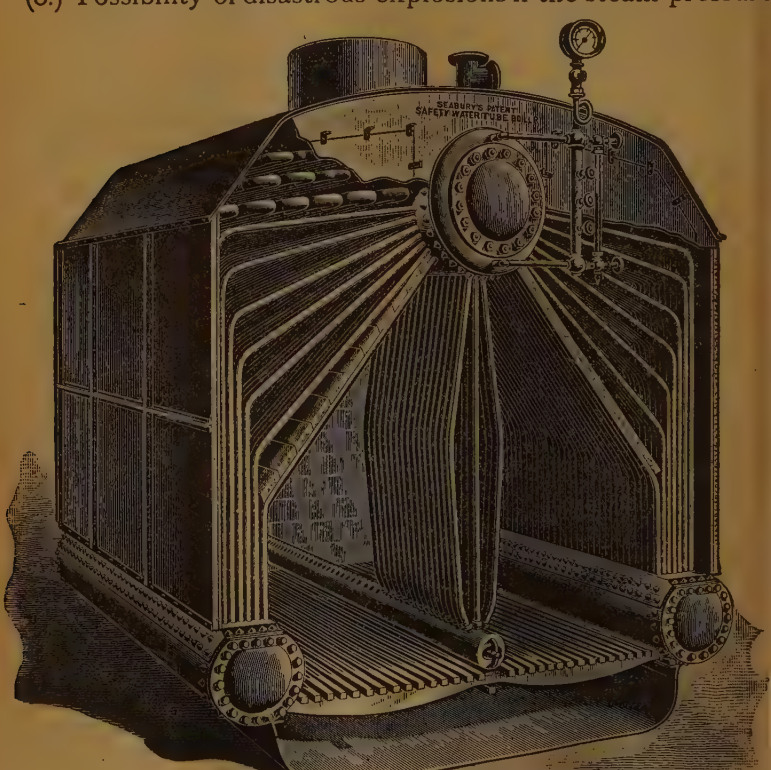


FIG. 49.—Types of Water-tube Boilers, IV.—The Seabury Boiler. This model has three lower-water drums, connected, as shown, with the single steam and water drum at the top. The furnace in this boiler is shown divided into two sections. Above the boiler tubes is a series of straight tube coils for heating the feed water.

should run too high, or part of the heating surface should collapse from overheating at low water.

The repairs in such emergencies are always extensive.

183. What are the advantages of water-tube boilers?

(1.) Comparative immunity from explosions, as the amount of water contained is small.

If any damage is done, it is usually in the tubes, which, in most cases, may be replaced at small expense and trouble.

(2.) Great lightness, as the material may be, even for high pressures, comparatively thin with little bracing. The amount of water contained is also small.

(3.) The possibility that the boiler may be built together

FIG. 50.—Detail of Lower Manifold of one Model of Seabury Boiler, showing the method of expanding the water tubes into the upper sheet of the water drum.

on its foundation, and the need of only small hatch entrances in the boiler rooms.

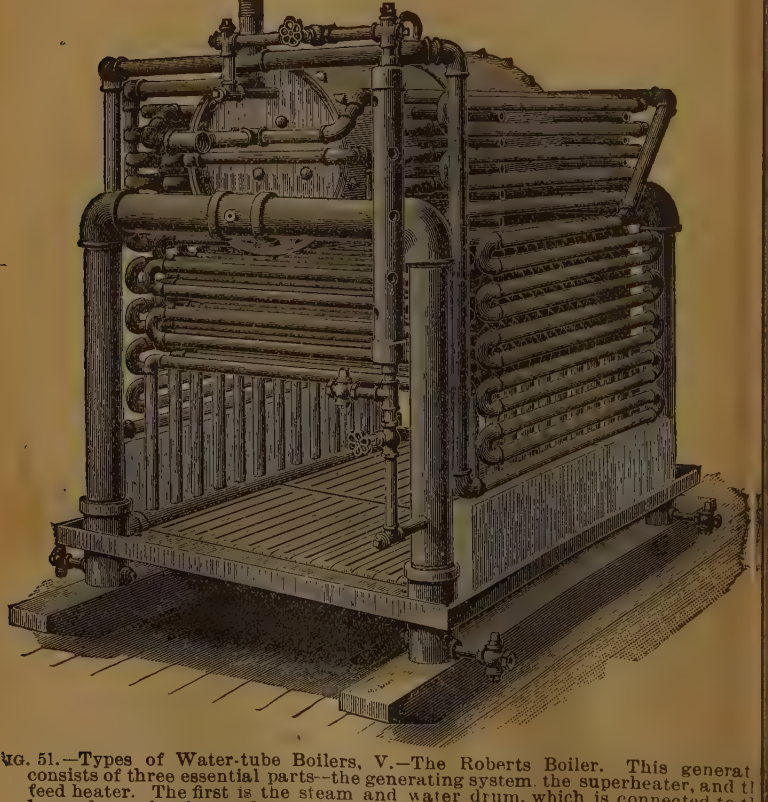
(4.) Rapidity of steam generation, owing to the small amount of water contained, as well as to great elasticity of structure.

(5.) Ability to stand forced draft and rapid cooling, owing to elasticity of structure.

184. What are the disadvantages of water-tube boilers?

(1.) Great sensitiveness in regard to quality of the feed-water and to a steady rate in its supply.

Fresh water is almost a necessity for water-tube boilers, in order to prevent scaling or incrustation; that might burn thr tubes through rapidly. The water-level has to be kept very



IG. 51.—Types of Water-tube Boilers, V.—The Roberts Boiler. This generat consists of three essential parts—the generating system, the superheater, and t feed heater. The first is the steam and water drum, which is connected to t lower drums by the up-flow coils, shown in detail in Fig. 52, and by the dow comers. The superheating coils run from top to base of the structure at righ angles to the down-comers.

steady, since, owing to the small amount of water contained strong evaporation might rapidly lower the water-level.

(2.) Sensitiveness in steam generation, as the small amoun

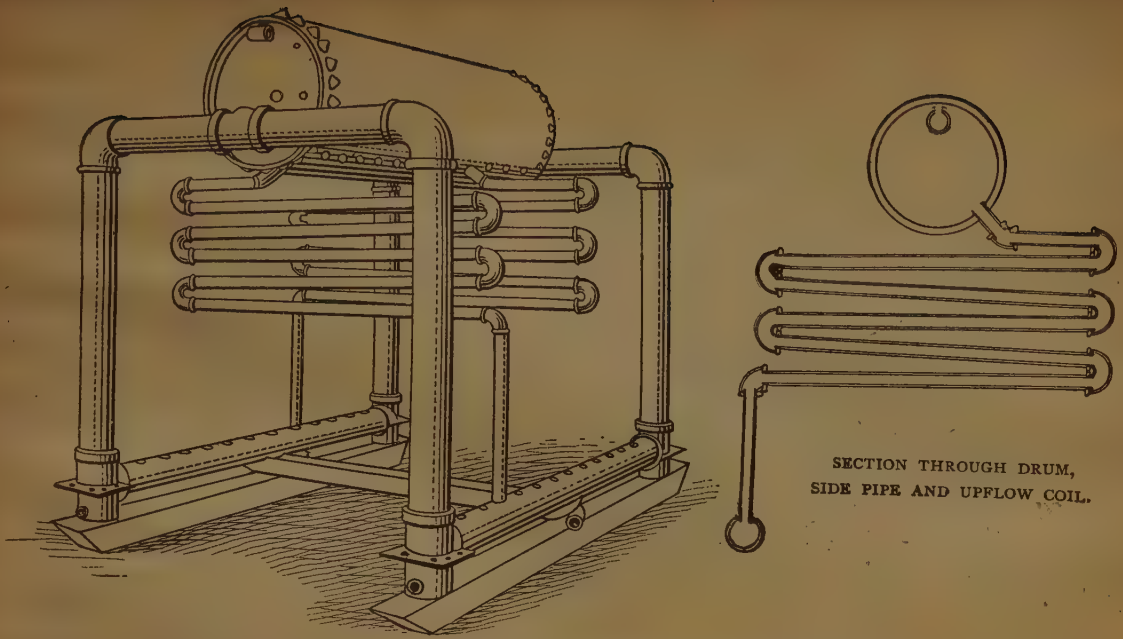


FIG. 52.—Constructional Details of the Roberts Tubular Boiler, showing two sets of tube coils attached to the steam and water drums; also, section through steam drum, side pipe and upflow coil.

of water affords no heat storage, and any change in the rate of combustion or evaporation will quickly affect the quantity and pressure of the steam. There is also a tendency to priming, as the water surface is quite contracted.

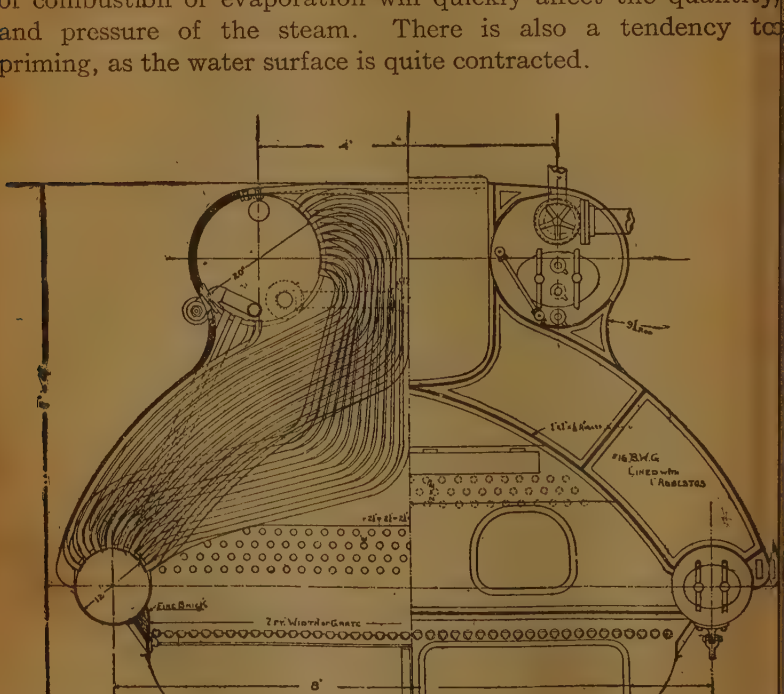


FIG. 53.—Types of Water-tube Boilers, VI.—The Mosher Double-drum Boiler for High-speed Torpedo Boats. This boiler has two upper and two lower drums which are connected by rows of bent tubing, inclined and connected, above and below, as shown. The two upper drums are also connected, below the water line, by a length of tubing, thus completing the water circulation.

(3.) A certain complication in form and use. Since such boilers are usually built in comparatively small units, they require a large number of them, with multiplied valves, joints, etc.

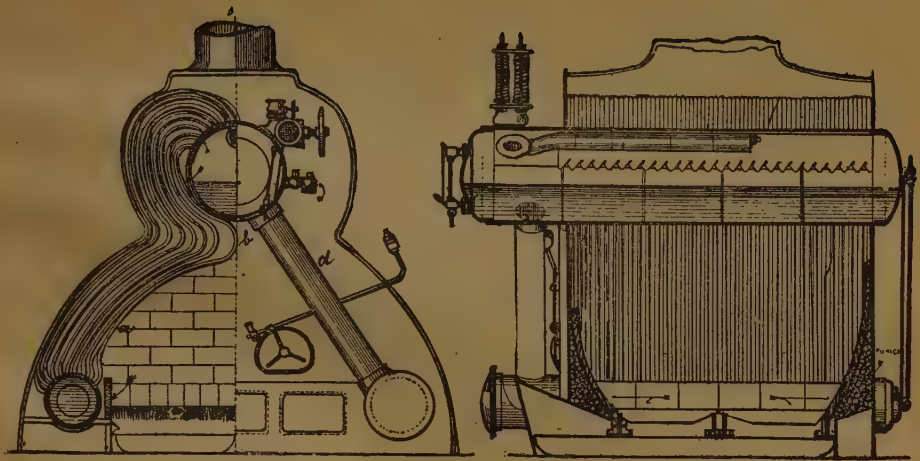


FIG. 54.—Types of Water-tube Boilers, VII.—The Thornycroft Boiler, "Speedy" Type. This boiler, as shown, has two lower and one upper drum, connected by a system of bent priming tubes, *a*, and also by two large down-comers, *d*,

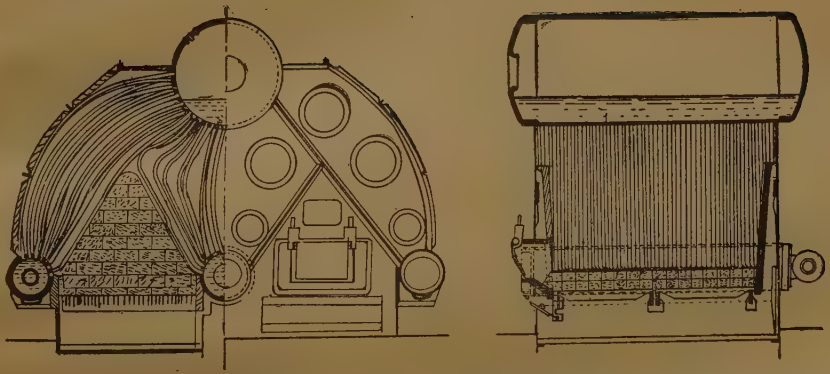


FIG. 55.—Types of Water-tube Boilers, VIII.--The Schultz-Thornycroft Boiler. This boiler has one upper and three lower drums connected by bent, drowned tubes.

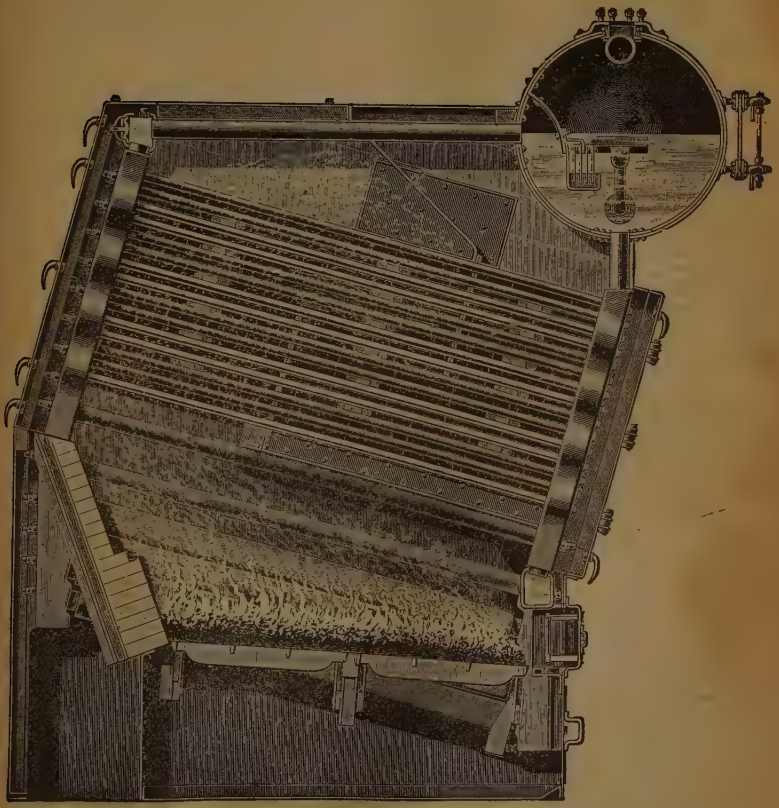


FIG. 56.—Types of Water-tube Boilers, IX.—The Babcock & Wilcox Marine Boiler. The water tubes of this boiler are straight and slightly inclined against the horizontal. They are expanded into sectional headers that allow cleaning and replacing of each tube separately.

They have a large number of tube-joints that are accessible only on the cooling and blowing-down of the boiler.

(4.) Loss of radiation, which is generally higher than in fire-tube boilers, on account of the greater exposure of fire-touched surfaces.

185. How does the matter of available fuel and feed-water supply affect the choice of a boiler?

The choice of a boiler may be affected by the fuel in such way as to make a deep fire-box desirable, as in locomotive boilers. It may be affected by the feed-water to make the removal of scale and sediment an easy matter, as in the Western river boiler; in a vertical boiler, or in a straight tube water-tube boiler.

186. How does the desired pressure affect the choice of a boiler?

The boiler may be built for a single cylinder engine which uses steam at low pressure; the leg boiler is, therefore, often found in connection with beam engines.

If medium pressure is desired, either the Scotch or locomotive boiler may seem suitable. For the highest pressures in use the water-tube boiler is, perhaps, the most practical.

187. How do the considerations of durability and easy tending, as well as immunity from repairs, affect the choice of a boiler?

Nearly all fire-tube boilers, if of large proportions to secure an easy evaporation on natural draft, will realize good durability, through heavy dimensions in their material, easy tending, by large units and by the large body of water contained, as well as small repairs by easy service.

In the small-tube "express" water-tube boiler, all these considerations are sacrificed to effect a saving of weight and to gain a higher speed, regardless of cost.

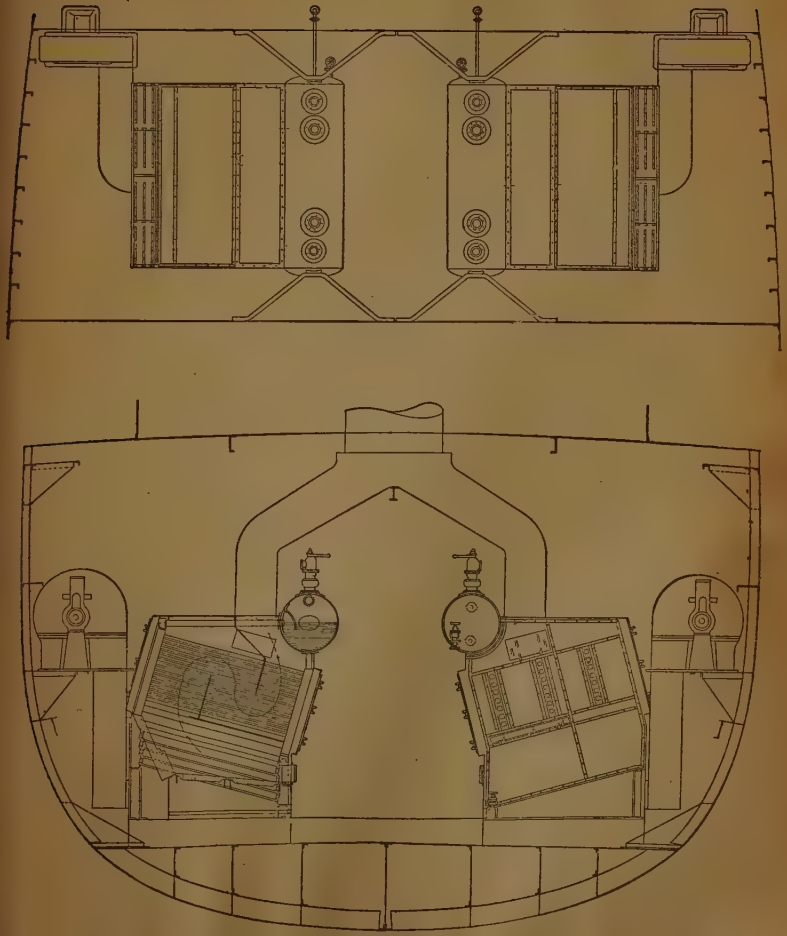


FIG. 57.—Plan and Transverse Section of a Ship's Hold, showing two Babcock & Wilcox boilers in position.

188. How do we ascertain the ability of a boiler to withstand high steam pressures?

By putting the boiler under a certain test or excess pressure it may be ascertained whether the boiler can stand the working pressure, without deformation, bulging or other indication of weakness.

189. What are the usual test pressures for boilers?

Fire-tube boilers are tested to one and a half times the working pressure and water-tube boilers to twice the working pressure.

190. Who makes this test for marine boilers in the United States?

The Federal officers of the Steamboat Inspection Service.

RULE X, 4.—Local inspectors, at their annual inspections of steam boilers, may cause to be removed from the surface of such boilers as are covered so much of said coverings as may be necessary to enable them to examine parts of the boilers which can not be properly examined from the inside, and shall examine in a thorough and careful manner, when practicable, either externally or internally, all parts of the shell of every boiler; and the masters, engineers, and owners of every steam vessel shall afford every facility necessary to carry out in the most effective and efficient manner the provisions of this section, and in no case shall an intermediate inspection be deemed any part of the regular annual inspection. (Secs. 4405, 4418, R. S.)

RULE II, 5.—It shall be the duty of inspectors when inspecting or re-inspecting a vessel to carefully examine all steam pipes passing through woodwork, and if in their judgment the same are deemed unsafe they shall have them provided with air space and fitted with metal collars. (Secs. 4405, 4418, R. S.)

RULE II, 6.—It shall be the duty of the inspector who inspects the boilers of any steamer to actually enter the boiler or boilers where it is possible to do so, and to thoroughly examine the interior of all such boilers to see that the braces are in place and of proper size, and to determine whether the boilers are in good condition, before granting a certificate of inspection, such examinations to be made after the hydrostatic pressure has been applied. A record shall be made in the boiler inspector's report of inspection showing whether or not the inspector did actually enter the boiler, and if he did not enter the boiler, he shall give his reasons for not entering it. (Secs. 4405, 4418, R. S.)

RULE II, 7.—It shall also be the duty of the inspectors to compel all floating structures, such as steam elevators (propelled by their own motive power), to have their whistles located on the front side of such super-structures having an elevation higher than the pilot house of the vessels. (Sec. 4405, R. S.)

Rule II, 8.—All steam whistles shall be placed not less than 6 feet above the top of the pilot house of steam vessels where the height of the smoke stack will admit the attachment of same blow its top, when not hinged for passing under bridges, except upon steamers navigating the Red River of the North, Yukon and similar rivers, and rivers whose waters flow into the Gulf of Mexico, and steamers of less than 100 gross tons, whose steam whistles shall be placed not less than 2 feet above the tops of their pilot houses; and all double-end ferry steamers, and steamers similarly constructed, shall have a steam whistle both fore and aft of the smoke stack, or one steam whistle on either the starboard or port side of the smoke stack, so that the steam, when whistle is blown, can be seen from either end of steamer; and it shall be the duty of inspectors to enforce this rule at the annual inspection. (Sec. 4405, R. S.)

CHAPTER SEVEN.

DETAILS OF CONSTRUCTION: FIRE-TUBE BOILERS.

191. Of what materials are the different parts of fire tube boilers constructed?

The principal material for nearly all parts is steel; iron is used sometimes in tubes, rivets and any smaller parts that require welding.

RULE I, 1.—Every iron or steel plate intended for the construction or repairs of boilers to be used on steam vessels shall be stamped by the manufacturer in the following manner:

At two diagonal corners, at a distance of about 8 inches from the edges, and at or near the center of the plate, with the name of the manufacturer, place where manufactured, and the number of pounds tensile stress it will bear to the sectional square inch, expressed in thousands.

Every iron or steel plate to be used in the construction or repairs of boilers for steamers navigated under the provisions of Title LI, Revised Statutes, which will be subject to tensile strain in said boilers shall be tested and inspected by an inspector duly authorized under the provisions of said title, and such plates shall not be stamped until they have been tested by the inspector, and each of such plates shall then be stamped by the manufacturer in the presence of the inspector with the minimum number of thousand pounds tensile stress it will bear to the sectional square inch.

All plates which conform to the physical, chemical, and other requirements prescribed by these rules shall be stamped by the inspector near the manufacturer's stamp, with the official stamp of the United States Steamboat-Inspecton Service, and with the initials of his name and a serial number. (Sec. 4430, R. S.)

RULE I, 2.—Plates may be tested and inspected at the mills for repairs to marine boilers or to be carried in stock, the report of such test to be in duplicate, one copy to be furnished through the supervising inspector to the local inspectors in the district where the purchaser of such material is located, and the other to the purchaser, who shall deliver a copy of the same to the parties using the material, who, in turn, shall submit the same to the local inspectors in the district where the material is to be used, before being assembled in the boiler. Steamers carrying such repair material to be used in emergencies shall carry the record of each sheet of such material on board. (Secs. 4430, 4431, R. S.)

RULE I, 3.—Boilers built since February 28, 1872, of material stamped and tested according to the requirements of section 4430, Revised Statutes, and having a record thereof in the office of the local inspectors in the district where the boiler was built or intended to be used, may be used for marine purposes, notwithstanding that such boilers may have been used for other purposes, if in the judgment of the local inspectors they are deemed safe. (Sec. 4430, R. S.)

RULE I, 4.—Steel plates shall be made by the open-hearth process, except that steel for plates to be used in the manufacture of boiler tubes may be made by the Bessemer process.

Open-hearth steel shall contain not more than .04 per cent of phosphorous nor more than .04 per cent of sulphur.

The manufacturer shall furnish the inspector, with each order tested, a certificate stating the process by which the steel was manufactured and a copy of the analysis of each melt. The analysis may, if deemed expedient by the Supervising Inspector General, be verified at the expense of the manufacturer. (Secs. 4405, 4430, R. S.)

For convenience of building, this material is arranged in numerous pieces, which are connected by joints to form the whole steam-tight structure.

192. How are these joints formed?

(1.) By lapping the single pieces over one another and securing them in place by rivets.

(2.) By butting them and arranging a common single or double butt strap that covers the joint and is riveted to both members.

(3.) By welding the parts together at the butt, or by screwing or expanding one member into another, as practiced with the tubes.

193. What styles of riveting are commonly used in joints of boilers?

The riveting of joints is the most common style of connec-

RULE I, 5.—When the tensile strength determined by the test is less than 63,000 pounds, the minimum elongation shall be 25 per cent for plates three-fourths inch and under in thickness and 22 per cent for plates over three-fourths inch in thickness. The quench bend specimen shall bend through 180° around a curve the radius of which is three-fourths the thickness of the specimen. When the tensile strength determined by the test is 63,000 pounds or greater, the minimum elongation shall be 22 per cent for plates three-fourths inch and under in thickness, and 20 per cent for plates over three-fourths inch in thickness. The quench bend specimen shall bend through 180° around a curve the radius of which is one and one-half times the thickness of the specimen. (Sec. 4430, R. S.)

RULE I, 6.—The tensile strength shall be not less than 45,000 pounds per square inch. The elongation shall be not less than 15 per cent. The reduction of area shall be not less than 15 per cent for 45,000 pounds tensile strength, and for each increase of 1,000 pounds tensile strength up to 55,000 pounds, an addition of 1 shall be made to the required percentage of reduction of area. The bend test specimen shall bend cold through 90° around a curve the radius of which is not greater than one and one-half times the thickness of the specimen. (Sec. 4430, R. S.)

RULE I, 7.—Tension test specimens shall be milled with the following dimensions: Length at least 16 inches, ends from 1½ to 3½ inches wide by about 3 inches in length, and parallel section at center 1 to 1½ inches wide by 9 inches in length. The percentage of elongation shall be measured in a gauge length of 8 inches.

Where specimens are to be tested on the testing machines of the Steamboat-Inspection Service, they shall be 1 inch wide at parallel section in center, and shall not exceed 2 inches in width on the ends.

Bend test specimens shall be at least 12 inches in length and from 1 to 3½ inches in width, and the full thickness as rolled. The edges may be planed. The corners shall not be rounded, but the sharpness may be removed with a fine file. After bending, the specimens shall show no cracks or flaws on the outside of the bent portion.

Bend test specimens for steel plates, before bending, shall be heated to a cherry red as seen in the dark, and quenched in water the temperature of which is about 82° F.

Two tension and two quench bend tests shall be made from each plate as first rolled from the billet, slab, or ingot.

tion, and may be arranged with one, two or three rows of rivets, according to the strength required in the joint.

Single riveting is the weakest arrangement, and is used where relatively little strain comes on the joint; while double and triple riveting is used in all the joints that have to resist great strains.

194. How are the holes for the rivets produced?

The rivet holes in the boiler plates may be produced by punching. This is, however, considered undesirable. Drilling is the best modern practice and gives the strongest work.

195. How are rivets driven?

Rivets are driven either by hand or by power.

Power-driven rivets are considered superior on account of the greater closing pressure exercised. Hand-driven rivets have to be used in places inaccessible to a machine.

196. Is the riveting sufficient for securing steam-tight work?

No; riveting has to be supplemented by caulking to secure complete tightness. Caulking makes use of the quality of malleability of steel, that allows the metal of one part to be

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RULE I, 5.—*Continued.*

The tension test specimens shall be cut from diagonal corners and the bend test specimens shall be cut from the other diagonal corners.

The finished material shall be free from all injurious defects, and shall have a good and workmanlike finish.

All measurements of test specimens and material shall be made by any standard American gauge, and record of tests shall be submitted on Form 934. (Secs. 4405, 4430, R. S.)

RULE II, 9.—It shall be the duty of both the hull and boiler inspectors to be present when the boiler is being tested by hydrostatic pressure, and the hull inspector, as well as the boiler inspector, shall observe and note the indication upon the gauge.

It shall also be the duty of both the hull and boiler inspectors to examine all pumps, hose, and other fire apparatus and to see that the hose is subjected to a pressure of 100 pounds to the square inch, and that the hose couplings are securely fastened in accordance with these rules. (Secs. 4405, 4417, 4418 R. S.)

RULE II, 10.—Local boards shall report forthwith to their supervising inspectors in detail all accidents of a serious character—such as collisions, founderings, sinkings, fires—and all other casualties of interest to or affecting the steamboat service in their respective districts. (Sec. 4405, R. S.)

driven into still closer contact with some other part by the blow of the caulking tool.

197. Which joints are most severely strained?

The longitudinal joints of the circular shells are the most strained, as they have to resist the whole steam pressure.

The strain in the circumferential joints is never so severe,

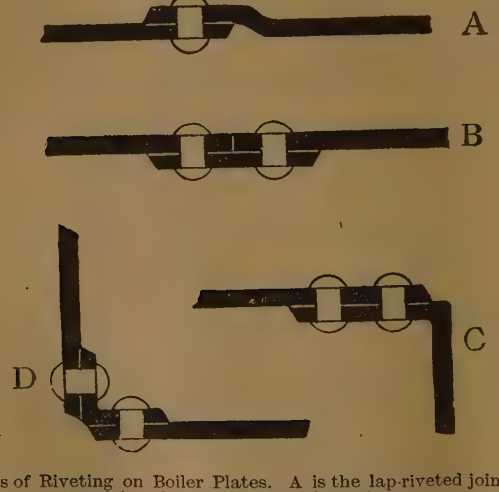

FIG. 58.—Details of Riveting on Boiler Plates. A is the lap-riveted joint; B, the single butt-strap joint; C and D, details of riveting at corners.

as the tubes and bracing take care of a large part of the pressure, thereby relieving the joint materially.

RULE II, 2.—The working steam pressure allowable on cylindrical shells of boilers, constructed of plates inspected as required by these rules, when single riveted, shall not produce a strain to exceed one-sixth of the tensile strength of the iron or steel plates of which such boilers are constructed; but where the longitudinal laps of the cylindrical parts of such boilers are double riveted, and the rivet holes for such boilers have been fairly drilled instead of punched, an addition of 20 per cent to the working pressure provided for single riveting shall be allowed.

The pressure for any dimension of boilers shall be ascertained by the following rule, viz.: Multiply one-sixth of the lowest tensile strength found stamped on the plates in the cylindrical shell by the thickness—expressed in inches or part of an inch—and divide by the radius or half diameter, also expressed in inches, and the result will be the pressure allowable per square inch of surface for single riveting, to which add 20 per cent where the longitudinal laps of the cylindrical parts of such boiler are double riveted, when all the rivet holes of such boiler, including steam and mud drums, have been fairly drilled and no part of such holes has been punched. The pressure allowed shall be based on the plate whose tensile strength multiplied by its thickness gives the lowest product. (Sec. 4433, R. S.)

198. Upon what does the arrangement of the plates in the boiler depend ?

(1.) The arrangement of the plates depends principally upon the size, large sizes being difficult to manufacture.

(2.) Questions of repair or replacement may make certain sizes desirable, as in tube-sheets, furnaces, etc.

(3.) Sometimes the position of the joint decides, for reasons of accessibility or ready cleaning, etc.

199. How are the corner joints made ?

Corner joints are usually made by flanging one of the plates and lapping it to the other one.

This is done in nearly all heads.

200. What influence has the form of the pieces upon their fitness to resist the pressure of the steam ?

The plates are arranged, as far as possible, in cylindrical form, since, where there is inside pressure, this is the only one that requires no additional reinforcement.

Large cylindrical parts, with outside pressure, require some additional reinforcements; while flat surfaces, or those curved to less than a semi-circle, require that all their capacity of resistance be provided from the outside, as with the relatively light weight only a very small area is self-supporting.

201. How is this additional strength provided ?

For large cylindrical parts additional strength is provided by staying to the shell, or by concentric, circumferential stiffening rings, sometimes added as an independent piece, sometimes provided by corrugations in the sheet itself.

For flat or nearly flat surfaces bracing is resorted to. Bracing consists in connecting different sections of the surface to rigid points, capable of bearing the load.

This is done sometimes by connecting two opposite flat surfaces together, thus counteracting in each sheet the ten-

dency to bulge; sometimes by extending the braces to the shell and sometimes by hanging the sheet up to rigid girders that transfer the pressure to the corner plates.

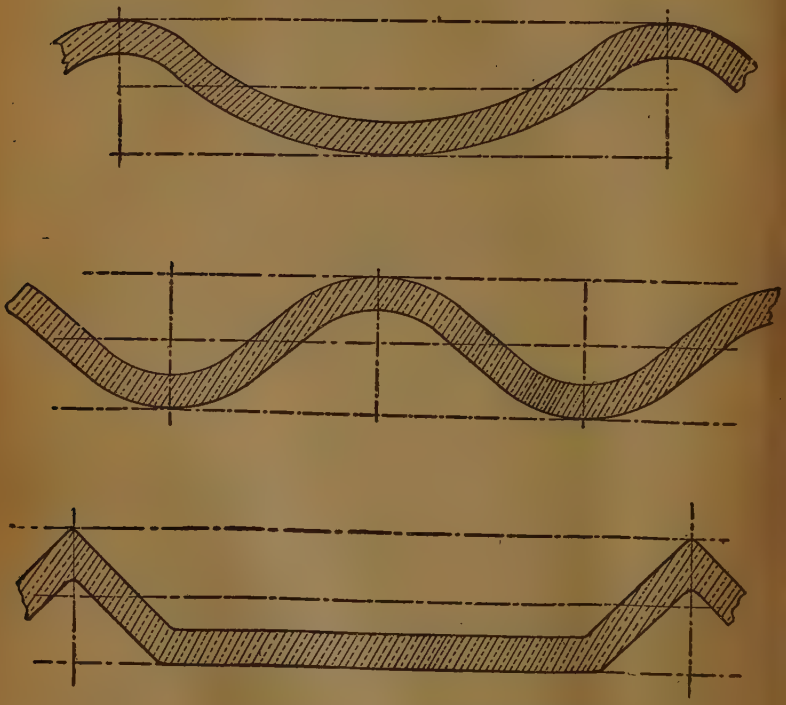

FIG. 59.—Three Types of Furnace Corrugations.

202. How do openings affect the strength of the plates?

Openings weaken the plates and additional local strength must be provided, in some cases, by riveting reinforcing pieces around the openings; in others by flanging the edge of the opening inward. (See manholes.)

203. What is the principal duty of the shell?

The shell provides the structural foundation of a fire-tube boiler, from which most of the other parts take their support. It must, at the same time, resist internally the pressure of the steam contained within it. It may have openings for manholes, domes and fittings, and usually connects to the foundation.

204. What is the construction of the shell?

The shell is built in one or more courses, according to its length. Each course may, circumferentially, consist of one or more sheets, preferably only one, as joints are the weakest part, and have to stand, in this case, the whole strain of the steam pressure. Shell-plates are usually the heaviest plates, for large Scotch boilers and high pressures, running as high as $1\frac{1}{2}$ inches in thickness.

For large work the longitudinal joints are, usually, triple riveted and double butt-strapped, and require great care in fitting, riveting and caulking. The circumferential seams are formed by one course lapping over the other, or over the heads.

205. What is the principal duty of the heads?

The heads close the ends of the boiler, and offer a support for the tubes and furnaces.

Being flat, they have to be braced against the pressure,

RULE II, 17.—Formula for girders over back connection and other flat surfaces:

$$\text{Working pressure} = \frac{C \times d^2 \times T}{(W - P) \times D \times L}$$

Where W = extreme width of combustion box in inches.
P = pitch of supporting bolts in inches.
D = distance between girders from center to center in inches.
L = length of girder in feet.
d = depth of girder in inches.
T = thickness of girder in inches.
C = 550 when the girder is fitted with 1 supporting bolt.
C = 825 when the girder is fitted with 2 or 3 supporting bolts.
C = 917 when the girder is fitted with 4 or 5 supporting bolts.
C = 963 when the girder is fitted with 6 or 7 supporting bolts.
C = 990 when the girder is fitted with 8 or more supporting bolts.

where the tubes or furnaces do not fill this office. The heads support a large number of fittings and contain manholes, handholes and fire doors.

206. How are the heads constructed?

The heads are made in one or more sheets, according to size. They are usually flanged around their edges for connection to the shell.

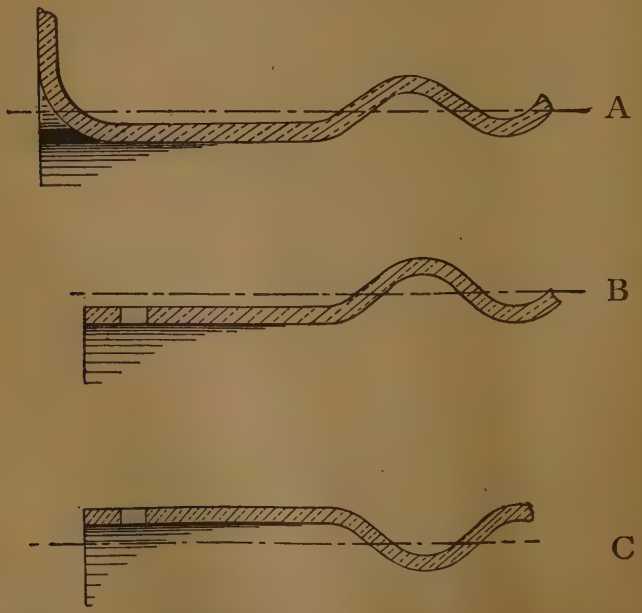

FIG. 60.—Three Types of Furnace End. A is a flanged end; B, small end at front; C, large end at front, for making removal easy.

207. What is the principal duty of the furnaces?

The principal duty of the furnaces is to provide a space for the combustion of the fuel; support the grates that carry the burning fuel, and provide a storage space for the ashes.

208. How are the furnaces built?

The furnaces take different forms:

(1.) In Scotch boilers they are usually circular, with corrugations, or stiffening rings riveted between short flanged pieces.

RULE II, 13.—The tensile strength of steel used in the construction of corrugated or ribbed furnaces shall not exceed 67,000 and be not less than 54,000 pounds; and in all other furnaces the minimum tensile strength shall be not less than 58,000 and the maximum not more than 67,000 pounds. The minimum elongation in 8 inches shall be 20 per cent.

All corrugated furnaces having plain parts at the ends not exceeding 9 inches in length (except flues especially provided for), when new, and made to practically true circles, shall be allowed a steam pressure in accordance with the following formula:

$$P = \frac{C \times T}{D}$$

LEEDS SUSPENSION BULB FURNACE.

$$P = \frac{C \times T}{D}$$

Where P = pressure in pounds.

T = Thickness in inches, not less than five-sixteenths of an inch.

D = mean diameter in inches.

C = 17,300, a constant, determined from an actual destructive test under the supervision of the board, when corrugations are not more than 8 inches from center to center and not less than 2¼ inches deep.

MORISON CORRUGATED TYPE.

$$P = \frac{C \times T}{D}$$

Where P = pressure in pounds.

T = thickness in inches, not less than five-sixteenths of an inch.

D = mean diameter in inches.

C = 15,600, a constant, determined from an actual destructive test under the supervision of the Board of Supervising Inspectors, when corrugations are not more than 8 inches from center to center and the radius of the outer corrugations is not more than one-half of the suspension curve.

(In calculating the mean diameter of the Morison furnace, the least inside diameter plus 2 inches may be taken as the mean diameter, thus—

Mean diameter = least inside diameter + 2 inches.)

FOX TYPE.

$$P = \frac{C \times T}{D}$$

Where P = pressure in pounds.

T = thickness in inches, not less than five-sixteenths.

D = mean diameter in inches.

C = 14,000, a constant, when corrugations are not more than 8 inches from center to center and not less than 1½ inches deep.

A certain longitudinal elasticity, as provided by the corrugation, is desirable to prevent excessive strain through expansion.

The ends extend into flanges of the heads, or are flanged themselves, being often arranged in such manner that furnaces can be removed without disturbance of any other part.

In vertical boilers the furnaces are plain, circular courses, concentric to the shell, and stayed to it.

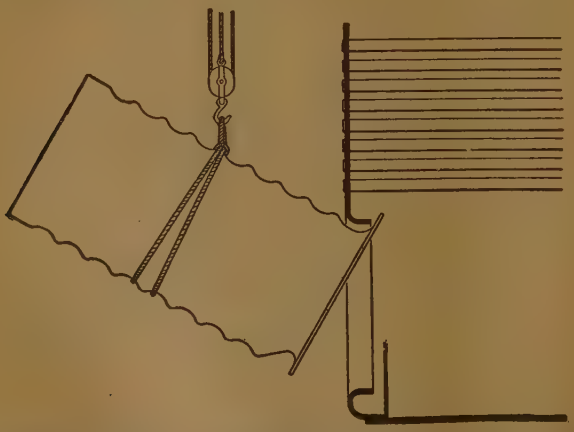

Fig. 61.—Method of Removing a Cylindrical Furnace from its Place in the Boiler.

(2.) In leg and locomotive boilers the furnace is box-shaped, surrounded by shell and heads and stayed thereto. It is usually built with top and side sheets and two heads flanged at the edges. The bottom is made tight by fitting a solid, wrought-iron ring, or flanged plates, between the shell and the furnace sheets.

The flat surfaces are stayed to shell and heads by numerous stays. These cramp the narrow space between the sheets, and make the so-called "legs" difficult to clean and repair.

(3.) In Western river boilers the top of the furnace is formed by the shell of the boiler, while the sides and ends are built up in brick.

209. What is the principal function of the combustion chamber?

As its name indicates, the combustion chamber is for providing space for the combustion, to give the gases and air time and occasion to intermingle and unite.

210. How is the combustion chamber built?

The combustion chamber is built in box form, with flat top, and ends and sides that follow the shape of the shell.

It is most frequently divided into several parts, corresponding to the number of the furnaces, by narrow water-spaces. A large number of stay-bolts connect these several divisions together, as well as support them from the shell and back head. The front head of the chamber connects to, and is

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The section area of pins to resist double shear and bending, accurately fitted and secured in crow feet, sling, and similar stays, shall be at least equal to eight-tenths of the required sectional area of the brace. Breadth across each side and depth to crown of eye shall be not less than .3 of diameter of pin. In order to compensate for inaccurate distribution the forks shall be proportioned to support two-thirds of the load, thickness of forks to be not less than .66 of the diameter of pin.

The combined sectional area of rivets used in securing tee irons and crow feet to shell, said rivets being in tension, shall be not less than the required sectional area of brace. To insure a well-proportioned rivet point, rivets shall be of sufficient length to completely fill the rivet holes and form a head equal in strength to the body of the rivet. All rivet holes shall be drilled. Distance from center of rivet hole to edge of tee irons, crow feet, and similar fastenings shall be so proportioned that the net sectional areas through sides at rivet holes shall equal the required rivet section. Rivet holes shall be slightly countersunk in order to form a fillet at point and head.

When sling stays are connected by pins to angles secured to shell, said angles shall be of sufficient depth to resist shear. Section to resist shear shall be determined by the following formula:

$$A = D \times 2T$$

$$D = \frac{A}{2T}$$

Where A = sectional area of pin.
D = depth from edge of pin hole to end of leg.
2T = thickness of two angles.

held in position by, furnaces or flues, and, in the upper part, by the tubes.

The tops, if flat, are stayed to the shell, or have independent girders, strong enough to transfer the bending strain to the rigid corners. The tops round up sometimes from the back of the chamber, with independent girders, or stays, to the boiler back head.

All the water-spaces should be large enough to allow cleaning, as well as to provide an active circulation of the water through them.

211. What is the duty of the tubes?

The tubes connect the combustion chamber with the uptake in such form as to provide the greatest amount of heat-absorbing surface.

212. How are the tubes constructed and fastened?

For the purpose of heat-absorption, the diameter should be as small as possible. There is a limit, however, as when it is too small there is danger of choking by cinders, soot, etc. In

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ADAMSON TYPE.

RULE II, 13.—*Furnaces.*

When plain horizontal flues are made in sections not less than 18 inches in length, and not less than five-sixteenths of an inch thick, and flanged to a depth of not less than three times the diameter of rivet holes plus the radius at furnace wall (inside diameter of furnace), the thickness of the flanges shall be as near the thickness of the body of the plate as practicable.

The radii of the flanges on the fire side shall be not less than three times the thickness of plate.

The distance from the edge of the rivet hole to the edge of the flange shall be not less than the diameter of the rivet hole, and the diameter of the rivets before driven shall be at least one fourth inch larger than the thickness of the plate.

The depth of the ring between the flanges shall be not less than three times the diameter of the rivet holes, and the ring shall be substantially riveted to the flanges. The fire edge of the ring shall terminate at or about the point of tangency to the curve of the flange, and the thickness of the ring shall be not less than one-half inch.

The pressure allowed shall be determined by the following formula:

ADAMSON FURNACES IN SECTIONS OF NOT LESS THAN 18 INCHES IN LENGTH.

$$P = \frac{57\,6}{D}\left[\ (18.75 \times T) - (1.03 \times L)\ \right]$$

Where P = working pressure in pounds per square inch.
D = outside diameter of furnace in inches.
L = length of section in inches.
T = thickness of plate in sixteenth of an inch.

spacing the tubes enough room should be left between them for rapid and efficient circulation of the water.

Their size ranges from 2 inches diameter up to 4 inches diameter, with a space of 1 to 1¼ inches between them. A special style of tubes are the large flues, as fitted in Western river steamers, which range from 10 to 16 inches in diameter. To increase the heat-absorbing capacity of the tubes, internal ribs are sometimes rolled into them, or spiral strips of thin sheet steel, so-called retarders, are laid into them, that compel the gases to touch the walls of the tubes more intimately. By the possibility of removal the retarders offer no obstacle to tube-sweeping, while both types improve the economy, particularly with forced draft.

The joints of the tubes in the tube-sheets are made by plain expanding, by expanding and beading or by screwing.

Screwing is done with a limited number of extra heavy tubes, that act as stays to support the tube-sheets. In this case the rest of the tubes need only plain expanding.

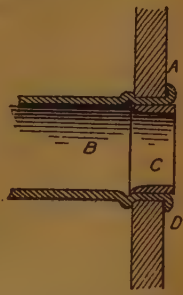


FIG. 62.—Connection of Tube in Tube-sheet. A is the tube-sheet; B, the tube; C, ferrule to prevent overheating of tube; D, beading of tube.

If no screw-tubes are fitted the support of the tube-sheets falls on all the tubes, and they are then beaded over at their ends to prevent slipping out of the sheets. The outer end of the tube is usually swelled up a little, to facilitate both fitting and removal.

Perfect fit of the tubes in the plate is often hard to retain, as the joints may become leaky, when the tubes expand more than the surrounding parts of the boiler.

Particularly under forced draft great inconvenience from

RULE II, 13.—*Continued.*

Given a furnace 44 inches in diameter, 48 inches in length, and one-half of an inch thick. Substituting values in formula, we have

$$P = \frac{57.6}{44}\left[(18.75 \times 8) - (1.03 \times 48)\right] = 1.309\ (150 - 49.44) = 131 \text{ pounds.}$$

the leakage of the tube-joints is experienced in both the Scotch and locomotive boilers.

The tube-plate and tube ends seem to get overheated by lack of sufficient water circulation near the sheet.

To prevent the overheating of the tube ends, so-called ferrules of cast iron are fitted that seem to improve the condition somewhat.

The expanding is usually done by roller expanders, while for beading a sort of caulking tool is used.

The tubes are now manufactured generally in two ways, viz.: welding from wrought-iron sheets, or drawing solid from a steel billet. The second is the later and better practice, but wrought-iron welded tubes are still used to a considerable extent.

213. What is the duty of the uptake?

The uptake collects the gases from the tubes of one or more boilers for delivery to the funnel. It may be a structure independent of the boiler or an integral part of it, as frequently found in leg boilers.

214. How is the uptake constructed?

The independent, or dry, uptake is usually a box built up from plates and angles. It may be of light material, as it is exposed to no pressure. By double sheets, frequently, an air space is arranged, to prevent too high a radiation of the heat of the gases into the fire room.

Large doors are provided in the front of the uptake, for easy access to the tubes, for cleaning and inspection.

The wet uptake is found in vertical boilers in form of a

LAP-WELDED BOILER TUBES UP TO AND INCLUDING 4 INCHES IN DIAMETER.

All lap-welded tubes shall be made of charcoal iron, or mild steel, made by any process.

SURFACE INSPECTION.

Tubes shall be free from defective welds, cracks, blisters, scale, pits and sand marks.

cone between the upper tube sheet and the top head, and in leg boilers in a shape that varies from box form to cylindrical form. The cylinder is constructed in courses, and extends upward, forming the inside lining of the superheater, being stayed in all surfaces to the nearest members.

A recess formed from the front head affords access to the tubes for cleaning and inspection, being closed by doors, to prevent the escape of the gases into the fire-room.

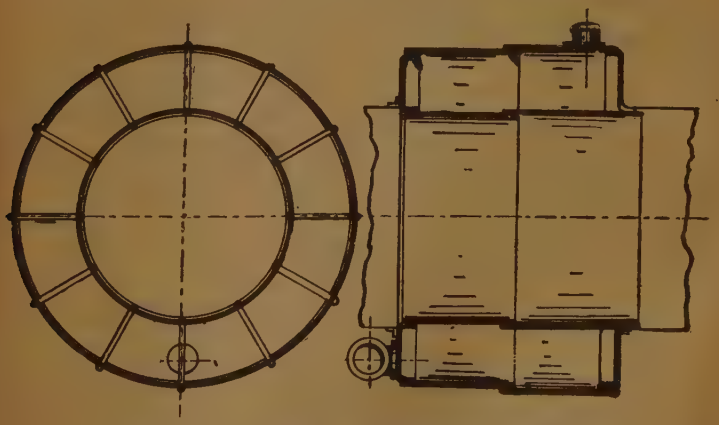


FIG. 63.—Details of Superheater, as described in Section 216.

215. What is the duty of the superheater?

The superheater is provided for the purpose of drying the steam and evaporating any water that may be carried into the steam by foaming in the boiler. In the present state of boiler construction it is frequently omitted.

LAP-WELDED BOILER TUBES.—*Continued.*

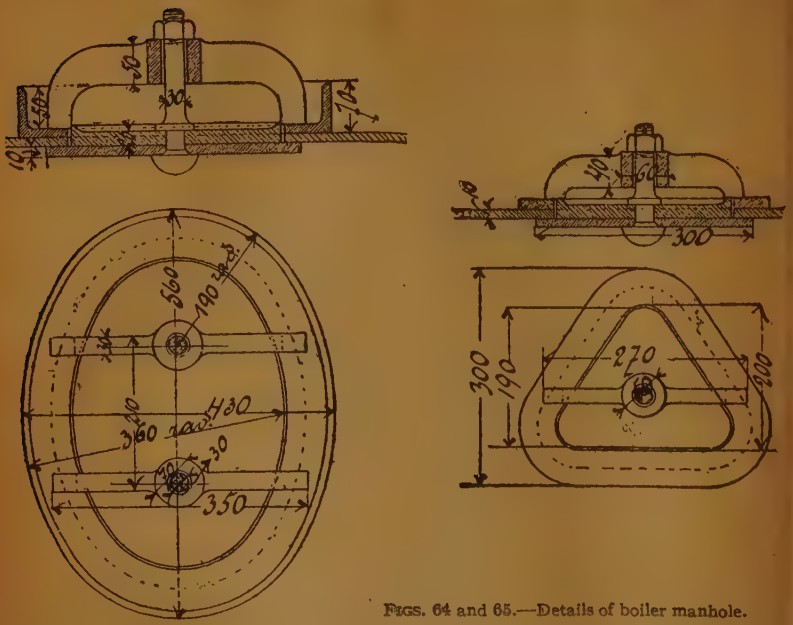
The following tests shall be made before shipment by the manufacturer:

(*a*) A test piece 2 inches in length cut from a tube shall stand being flattened by hammering until the sides are brought parallel and separated by a distance not greater than three times the thickness of the metal, without showing cracks or flaws, with bend at one side being in the weld.

(*b*) A second tube shall have a flange turned over at right angles to the body of the tube and shall have a width equal to three-eighths of an inch.

All the work shall be done cold.

Each tube shall stand an internal hydrostatic pressure of 1,000 pounds per square inch and shall be struck near both ends while under pressure with a two-pound hammer or its equivalent without showing signs of weakness or defects.



FIGS. 64 and 65.—Details of boiler manhole.

RULE II, 15.—All holes for tubes shall be drilled and no part punched. Lap-welded and seamless tubes, used in boilers whose construction was commenced after June 30, 1910, having a thickness of material according to their respective diameters, shall be allowed a working pressure as prescribed in the following table, provided they are deemed safe by the inspectors. Where heavier material is used, pressure may be allowed as prescribed in first formula under the heading "Flues," for determining the working pressure of lap-welded flues. Any length of tube is allowable.

Outside Diameter Inches	Thickness of Material Inch	Maximum Pressure Allowed Pounds
2	.095	427
2¼	.095	380
2½	.109	392
2¾	.109	356
3	.109	327
3¼	.120	332
3½	.120	308
3¾	.120	282
4	.134	303
4½	.134	238
5	.148	235
6	.165	199

216. How is the superheater constructed?

The superheater is best known in connection with the leg boiler, where it takes the form of a large dome, in direct communication with the steam space. On certain boilers it is constructed as an independent body connected to the boiler by pipes.

Its form is cylindrical, with heads for the ends, flanged to receive the liner tube of the uptake. The shell is executed in courses, riveted similar to the boiler shell.

217. What use is made of steam domes and steam and mud drums?

Steam domes and steam drums afford a collecting space for the steam, to throw down any water that may have been carried up by priming.

Their use is decreasing, as an internal "dry pipe" performs the service, apparently, equally as well. They are constructed in cylindrical form, with flanged heads and connections to the boiler shell.

Mud drums are found in such types of boilers as use water containing a large amount of impurities; their construction is similar to that of steam drums.

218. What are the uses of manholes and handholes?

Manholes and handholes are provided for entering, clean-

CONCAVE HEADS.

For concave heads the pressure allowable shall be eight-tenths times the pressure allowable for convex heads.

NOTE.—To find the radius of a sphere of which the bumped head forms a part, square the readius of head, divide this by the height of bump required; to the result add height of bump which will equal diameter of sphere, one-half of which will be the required radius.

EXAMPLE.

Required, the working pressure of a convex head of a 54-inch radius; material, 60,000 pounds tensile strength and one-half of an inch thick. Substituting values and solving, we have

$$P = \frac{.5 \times 12{,}000}{27} = 222 \text{ pounds.}$$

The pressure allowable on a concave head of the same dimensions would be $222 \times .8 = 177$ pounds.

ing and inspecting the interior of the boiler. They are situated in the shell and heads, and should interfere as little as possible with the efficient staying of the boiler, while still allowing access to all surfaces that might be covered with scale.

The minimum size of manholes is 11 x 15 inches, except in special cases. They are usually oval or elliptical in shape, in order to allow the cover to be fitted on the inside of the sheet and held down by the pressure of the steam.

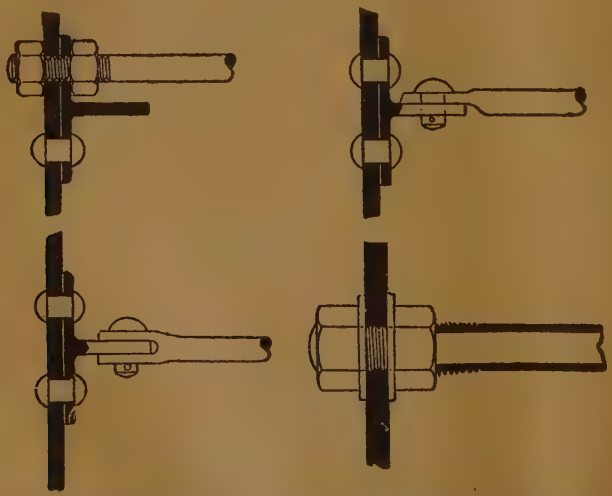


FIG. 66.—Several Methods of Bracing Boiler Plates by Rods Attached to Plate by T-pieces or Double Nuts.

The reinforcing ring or flange has a planed edge, on which the cover rests, with some packing between them. The covers require only one or two wrought steel dogs and heavy

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CONCAVE HEADS.—*Continued.*

To avoid grooving, the flanging shall be well rounded at the bend.

Bumped heads may contain a manhole opening flanged inwardly when such flange is turned to a depth of three times the thickness of material in the head.

Material used in the construction of all bumped heads shall possess the physical and chemical qualities prescribed by the Board of Supervising Inspectors for all plates subject to tensile strain, as required by section 4430, Revised Statutes.

bolts, to be secured in place. The body of the cover is made of cast iron or stamped steel.

219. What is the duty of the lagging?

The lagging is applied to the outside of the shell and some parts of the heads to prevent escape of heat by radiation.

For fire-tube boilers it is usually composed of felt, of asbestos fiber or of mineral wool, in which materials the qualities of non-conduction, of imperishability, and of non-inflammability should have due consideration.

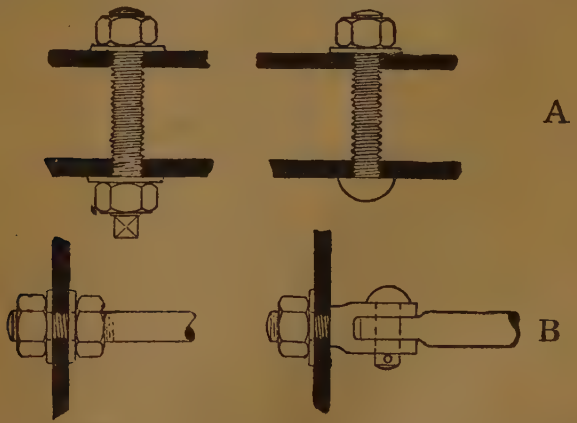

FIG. 67.—Boiler Bracing. A, stay bolts connected to plates; B, details of bracing.

Sometimes a frame is strapped to the boiler, that provides small squares for the support of the lagging in form of paste or cement, which are afterwards covered with thin sheet iron. This form allows great convenience in replacing and handling whenever necessary.

220. What are the methods of bracing and staying?

(1.) Independent bracing, where the brace connects to the supported surface only.

All sea valves or cocks secured to the skin of the vessel by bolts and connected to the engines or boilers by pipes shall be arranged so as to be accessible at all times, so that if a leak or defect occurs it can be reached.

(2.) Connecting bracing, where the brace supports the surface by connecting to an outside point.

221. What are the common forms of independent bracing?

(1.) On large, cylindrical surfaces, with outside pressure, independent, circumferential stiffening rings provide the needed strength against collapse in a longitudinal direction. They are spaced at short intervals, which in modern furnaces of the Scotch boiler type take the shape of continuous corrugations.

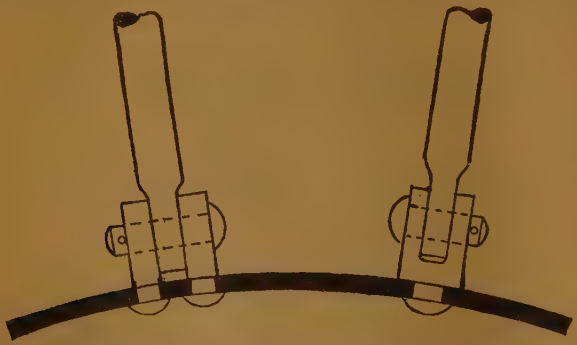

FIG 68.—Details of the Stay Connections of a Furnace Crown.

Older forms show structures, built up from short flanged cylinders, with stiffening rings riveted between the flanges, or have angle, or half round, iron rings, around a continuous smooth plate flue, separated from it by short nipples, for allowing water circulation under the rings.

(2.) On flat surfaces the independent bracing is provided by girders or crown-bars that transfer the bending strain to the

---

FLAT HEADS OF WROUGHT-IRON OR STEEL PLATE.

Where flat heads do not exceed 20 inches in diameter they may be used without being stayed, and the steam pressure allowable shall be determined by the following formula:

$$P = \frac{C \times T^2}{A}$$

Where P = steam pressure allowable in pounds.
T = Thickness of material in sixteenths of an inch.
A = one-half the area of head in inches.
C = 112 for plates seven-sixteenths of an inch and under.
C = 120 for plates over seven-sixteenths of an inch.
Provided, The flanges are made to an inside radius of at least 1½ inches.

rigid edges of the sheets. It is, for this reason, applied only to narrow surfaces, as on wide surfaces the girders would become too heavy to do the work effectively. The plate is hung up to a series of these girders, in regular intervals, by bolts screwed into the plate. The girders rest, by close-fitting feet, on the edge of the plate or heads, allowing the water to circulate underneath them, over the plate.

Generally the girders are arranged in pairs, spaced rigidly by rivets, to allow one set of bolts to pass up between them. The girders must be made with the necessary depth and thickness, to prevent any deflection of the surface they support.

222. What are the common forms of connecting bracing?

Connecting bracing is done by rods or plates that rigidly

NOTE.—***Water space stays.*** The combustion chamber stays usually range in diameter from about 1¼ to 1¾ inches, with a pitch of from 7½ to 8½ inches. These stays are screwed through the plates to be supported, and are secured by means of two nuts in all, one outside the boiler and the other inside the combustion chamber, the stay ends being riveted over the nuts. The plate is usually caulked round the stay to keep the joint tight. Occasionally the outside end of the stay is riveted over only, and the plate caulked round the stays. These stays are, under ordinary conditions, subject to a tensile stress, but this is usually augmented by a bending stress produced by the floating tendency of the combustion chamber, which, it will be observed, is a hollow chamber immersed in water. This lifting tendency strains the stays often to the point of fracture, and in consequence permitting corrosion to take place at a more rapid rate.

NOTE.—***Caulking of stays.*** When the stays are screwed into the plates the latter are caulked round the stays, to ensure tightness, a touch of mastic cement or red lead putty being placed on the face of the nut before screwing up.

NOTE.—***In modern high pressure boilers*** the wing and center combustion chambers are stayed together by a plate form of stay, and is connected by means of pins through the plate and through angle irons, riveted to the combustion chamber plates. This type of stay is fitted at the bottom of the combustion chambers, forming a segment round the lower parts.

NOTE.—***Combustion chambers.*** The bottoms of combustion chambers are often stiffened by means of angle or T steel segments, which are riveted on, and extend from the bottom for some distance up the sides. Certain makers also fit plate stays, between these angle segments of adjacent combustion chambers to keep them in position.

unite the two surfaces, and prevent their movement in the line of the pressure. The distinction of forms is in the manner of the attachment of the brace to the surfaces.

The attachment may be made by:

(1) Threaded ends of the brace that screw through the plate and are provided, either with nuts on outside only or with nuts on both inside and outside, or with heads riveted over, to secure substantial tightness and rigidity.

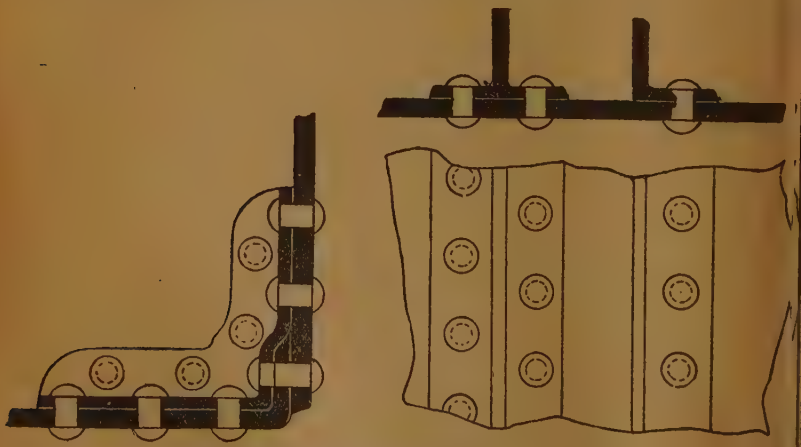

FIG. 69.—Details of Corner Angles or T-braces.

These screw-ends, as used in the main braces, are heavy bars that support generally the main heads.

To concentrate the bracing into as few main braces as possible, for sake of accessibility, stiffening is applied to the heads, in form of large, heavy washers or T-bars, that help to distribute the support over a large surface.

Around the manholes these heavy braces sometimes extend only from the head to the side of the shell, where they are held by riveted palms.

Screwed ends are most frequently used in the stays of the nar-

row water-spaces of the furnace legs and around the combustion chambers, either with nuts on the outside of each end, or with heads riveted over. These stay-bolts, in the most modern practice, are hollow through all or a part of their length, in order that escaping steam may give an indication of possible corrosion or breaking of the bolt. An older form is the socket bolt, a rivet passing through a thimble, that preserves the right spacing of the sheets and protects the bolt against corrosion.

(2.) Palms on the end of the brace that are riveted to the plate. The braces may be solid rods with forged palms, or plates, in special flanged form, or plate gussets connected by angle irons.

For long members the ends are frequently formed separately, two palms being connected together into a so-called "crowfoot," which is attached by a bolt to the forked end of the long bar. This gives also convenience for removal and repair of the long bolts, without disturbing the riveting in the crowfoot.

NOTE.—***Combustion chamber stays.*** It will generally be found that the marginal stays of combustion chambers are first affected by wear, and particularly the top row. Often the stays in this row develop minute cracks which may, however, on testing, be found to extend right into the body of the stay metal. The floating tendency of the combustion chamber (which, it should be observed, is simply a hollow vessel immersed in water) throws severe stresses on the stays, and generally, through time, results in straining the metal of the stays as described. The marginal stays having to support more surface than the inner stays are of larger section (often 1½ to 1¾ inches diameter).

NOTE.—***Combustion chamber girders.*** The combustion chamber top of single ended, and in some cases double ended boilers, is supported against collapse by girders. The girders are formed of two vertical steel plates each about ¾ or ⅞ inch thick, and between these plates stays are passed down and screwed into the top plate; nuts and overlapping washers are fitted above. The plates forming the girders are held together by rivets fitting through thimbles. The girder plates are often made overlapping on to the top plate at the sides, but some firms have the plates cut clear altogether. Under working conditions the girder plates are subjected to a compressive and bending stress, the compression being at the ends where the load is taken up by the back tube plate and combustion chamber plate, and the tensile stress acts at and near the center of the girder.

CHAPTER EIGHT.

DETAILS OF CONSTRUCTION: WATER-TUBE BOILERS.

223. Of what materials are water-tube boilers constructed?

Water-tube boilers are mainly constructed of wrought steel. In some boilers tubes of copper have been tried, but these have been practically abandoned, as being too easily affected by high temperatures, which seriously impair their strength. In some constructions the headers and pipe fittings are made of cast steel.

For the bottom drums, tubes, down-comers and headers of some models of water-tube boiler standard wrought-iron gas pipe is used.

224. How are the joints made in water-tube boilers?

The joints in the drums are either riveted longitudinally and at the flanged heads, or welded, this latter process having found increasing favor in modern practice. The connections of down-comers are made by riveted flanges or screwed connections.

RULE II, 24.—The working pressure allowable on cylindrical shells of water-tube or coil boilers, when such shells have a row or rows of pipes or tubes inserted therein, shall be determined by the following formula:

$$P = \frac{(D - d) \times T \times S}{D \times R}.$$

Where P = working pressure allowable in pounds.
D = distance in inches between the tube or pipe centers in a line from head to head
d = diameter of hole in inches.
T = thickness of plate in inches.
S = one-sixth of the tensile strength of the plate.
R = radius of shell in inches.
n = number of tube holes in a pitch. When tubes on any one row are pitched un equally, nd must be substituted in the formula for d.

Where rows of tubes are pitched diagonally, each diagonal ligament shall be not less tha three-fifths of each longitudinal ligament.

The tubes are either expanded or screwed into the tube-sheets, headers or chambers.

225. Is the form of the members of water-tube boilers such that additional strength is required for resisting the steam pressure?

The form of most members of water-tube boilers is cylindrical, with inside pressure, additional strength being needed only in some heads and in a few flat-sided water-chambers.

Heads are stayed, in manner similar to those of fire-tube boilers, with braces, or they are constructed as bumped heads, where they may require no additional strength. Some forms of headers are flat-sided, but only in narrow surfaces of sufficient thickness to be self-supporting. Around openings additional strength must be provided by reinforcing rings or flanges, similar to those in the fire-tube boilers. Where the tubes are expanded directly into the drums the sheet receiving them is usually made somewhat heavier, partly to provide additional strength and partly to allow additional bearing surface for expanding the tube-end.

226. What are the use and construction of the drums?

The top drum is made large enough to allow substantial fastening of all the tubes or headers.

Its capacity must be sufficient to allow a broad water-surface and as large a steam-space as possible. It should provide convenient positions for the fittings, manholes, etc., and be of sufficient diameter for efficient work of tube-expanding.

The bottom drums are often whole, flattened or half-cylinders for support of tubes or headers.

Some are quite small in diameter, principally with screwed joints, while others are large enough for access of workmen to do tube-expanding and cleaning.

227. What are the use and construction of the headers and water chambers?

The headers and water chambers are intended to secure quick discharge of the steam into the top drum from horizontal or slightly inclined tubes.

The headers unite a vertical row of tubes into one element, an arrangement convenient for replacing or plugging with leaky tubes.

The headers are round or square channels, with separate outlet or inlet, and are constructed in either wrought or cast steel.

The water-chambers, with their flat sides, lack the strength of the headers, and, therefore, must receive a large number of stay-bolts to keep their shape.

The outside face of the headers and chambers is usually provided with handholes, opposite to each tube opening, so as to afford good facility for cleaning, removing and replacing any straight tube, without disturbing any other member.

The great number of joints that have to be kept tight is, however, an inconvenience to the engineer. A special form of the water-chamber is the double chamber, usually connected with the double tube arrangement. In this chamber the outside part is devoted to the down-flow, while the inside part is devoted to the up-flow of the water or steam.

228. What are the use, construction and arrangement of the tubes and down-comers?

The tubes in a water-tube boiler provide the upward passage for the water at the time of heat absorption, while their position, in addition to baffle-plates, determines, in several types, the course of the gases to the stack. According to their form, as straight or bent tubes, they are frequently of solid drawn steel for the bent form, while lap-welded wrought iron is often chosen for the straight ones.

Their dimensions vary from 1 to 4 inches in diameter, while the thickness of their walls may range from $\frac{1}{16}$ to $\frac{1}{4}$ inch.

The straight tube boilers are usually arranged so that they may be inspected and cleaned internally, while most bent tube boilers do not allow of much inspection. The external cleaning is rather difficult, as the space is somewhat cramped.

The tubes of small thickness are sometimes galvanized on the outside, to secure greater immunity against corrosion.

The bent tubes lend themselves readily to the formation of gas passages by their arrangement in closely fitting, solid rows.

The double tube types have the heated tube open only at the end connected to the water chamber, while the other is closed by a cleaning plug.

They need, therefore, an inner tube in order to permit circulation of the water throughout the entire length.

Their fastening, in the double chambers, is made by coned, or screwed, joints.

The down-comers are principally for the purpose of affording the downward path in the circulation of the water.

They are usually tubes of large diameter, more or less directly connecting top and bottom drums.

In some boilers they are very important members, as insuring the support of the top drum and preserving the rigidity of the whole boiler structure.

In other boilers the regular down-comers are omitted, some of the heating tubes doing duty in their stead.

229. What is the use and construction of the casing?

The casing has the important duty of concentrating the effect of the fire upon the tubes.

It should possess, for this purpose, the least capacity for radiation and conduction of heat, which is realized in greater or less degree in the different constructions by dead air spaces, or lining with asbestos, fire brick, etc.

The lining of the casing has to serve the same purpose as the lagging on fire-tube boilers, being frequently a simple structural member, for the support of the top drums, tube ends, etc. It is constructed usually in parts, easily removed for cleaning the interior space, which are formed from light steel sheets and angles, lined by the respective non-conductor in one or more thicknesses, connected by bolts.

The lower parts of the casing around the grate are usually set with firebrick, as the only substance able to withstand the intense direct heat of the fire. Fire doors, ash-pit doors, stack connections and cleaning openings are arranged in the casing in substantial and air-tight manner.

230. What are the use and construction of the boiler saddles?

Boiler saddles support the boiler, so that it cannot be displaced by the movements of the ship, and at the same time distribute the concentrated weight of the boiler and its water over a broad surface through the numerous members of the hull structure. Particularly in shallow wooden ships, provision has to be made for this by the arrangement of substantial keelsons and girders.

The saddles consist generally of two or more cast or wrought iron girders, which may be arranged transversely, as in Scotch and leg boilers, or, longitudinally, as in some forms of water-tube boilers. The saddles are fitted to the form of the shell or legs, either directly, as with angle irons, or with cement or putty filling the interstices, as with cast-iron saddles. Legs with bolt connections are used for securing the boilers to their seats in some constructions, while with others, straps or stays with turnbuckles. To prevent a sliding in the longitudinal direction, chock pieces in form of brackets are fitted to one end of the boiler. The other end is left free to expand or contract under varying temperatures.

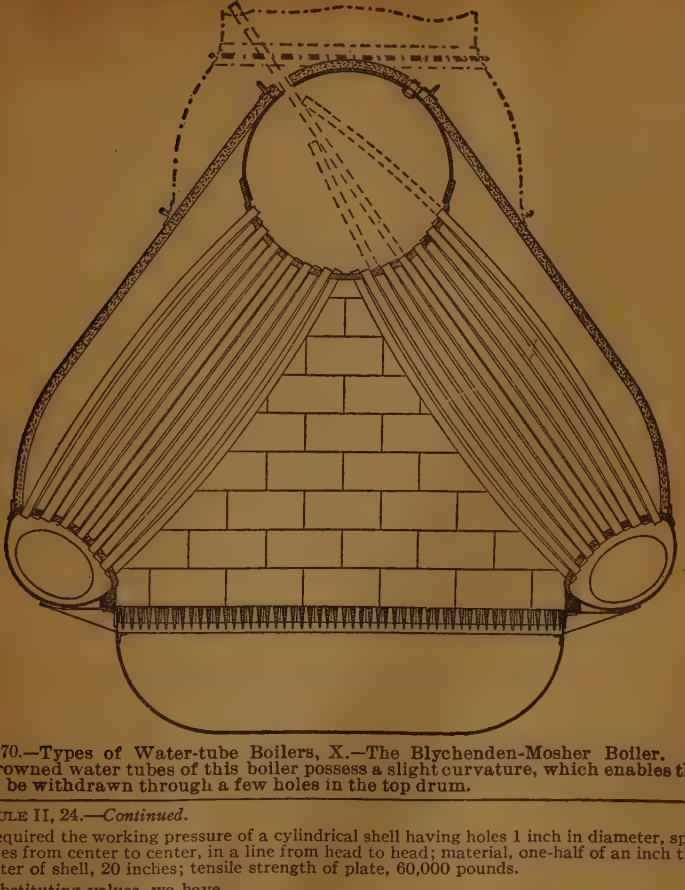

FIG. 70.—Types of Water-tube Boilers, X.—The Blychenden-Mosher Boiler. The drowned water tubes of this boiler possess a slight curvature, which enables them to be withdrawn through a few holes in the top drum.

RULE II, 24.—*Continued.*

Required the working pressure of a cylindrical shell having holes 1 inch in diameter, spaced 2 inches from center to center, in a line from head to head; material, one-half of an inch thick; diameter of shell, 20 inches; tensile strength of plate, 60,000 pounds.

Substituting values, we have

$$P = \frac{(2-1) \times 5 \times 10{,}000}{2 \times 10} = 250 \text{ pounds.}$$

RULE II, 24.—The formula for determining pressure on boilers of the so-called porcupine and similar types shall be as follows:

Multiply the vertical distance between the centers of the horizontal rows of tubes in inches by one-half the diameter of shell of boiler in inches, which gives the area upon which the pressure is exerted to break a diagonal ligament, then find the sectional area of the ligament at its smallest part and multiply by one-sixth the tensile strength of the material. This result divided by the area upon which the strain is exerted gives the working pressure per square inch, which is as follows: EFT ÷ CD = W, the working pressure, in which E, equals width of ligament in inches, F, thickness of material in inches. T, one-sixth of the tensile strength, C, distance between vertical centers, and D, one-half the inside diameter of the shell or central column.

CHAPTER NINE.

OPERATIVE DETAILS OF MARINE BOILERS HAVING TO DO WITH FUEL AND FIRE GASES.

231. Is there any difference in details of operation between fire-tube and water-tube boilers?

Not materially, since in both boilers the same operative elements are present.

232. What are the operative elements in marine boilers?

The operation of marine boilers concerns:

(*a*) Fuel and fire-gases; (*b*) water; (*c*) steam.

233. What details of construction concern the fuel and the fire gases?

(1.) Fire-door, furnace-front and ash-pit door.

(2.) Grate and grate-bearers, ash pan and bridge wall.

(3.) Uptake, smoke boxes and smoke-stack.

234. How are the furnace fronts and doors constructed and what are their uses?

In certain types of boiler the furnace fronts are tightly fitted to prevent the gases from escaping into the fire-room, serving at the same time for support of the doors and forward ends of the grates.

These fronts are made of wrought or cast iron and are fitted and bolted to the furnace opening. They are in double thickness, with an air-space between them that serves the purpose of reducing the radiation of heat. The inner one is usually fitted so that it can be easily replaced, as it burns out rapidly under the direct heat of the fire.

In some boilers the lower edge of the furnace front extends

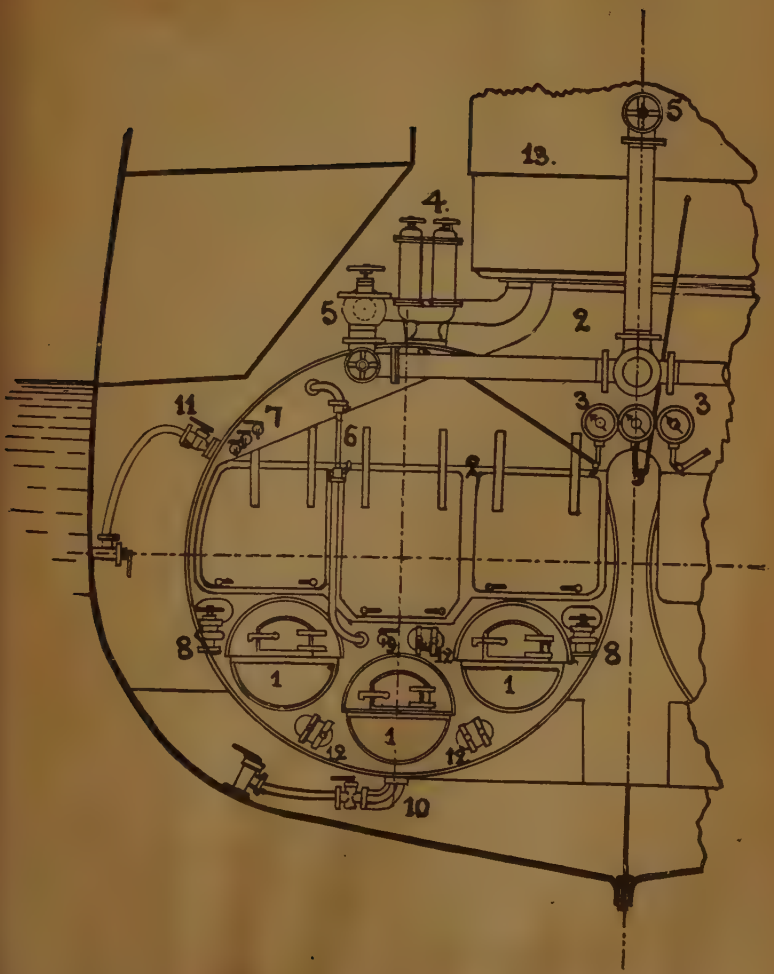

FIG. 71.—Scotch Boiler and Attachments, as Placed in the Ship. The parts shown are: The furnaces (1); the uptake and smoke boxes (2); steam gauges (3); safety valve (4); stop valve (5); water gauge (6); test cocks (7); feed checks (8); salinometer cock (9); bottom blow (10); surface blow (11); manholes (12); superheater (13).

inward with a sort of shelf, the so-called dead-plate, which gives support to the forward ends of the grate.

Besides the opening for the door and hinge-lugs to fasten it, there are usually a number of holes, in both thicknesses of the front, to allow a certain amount of air to enter the furnace, partly for cooling the front, partly to assist the combustion.

In certain forms of ash-pit forced draft the space in the furnace front is used for the inlet of the air, and the front, in

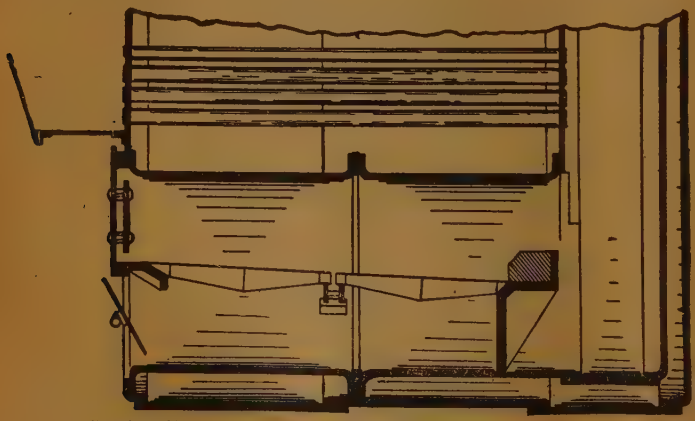

FIG. 72.—Section Through the Furnace and Combustion Chamber of a Scotch Boiler.

this case, is cast as a hollow body extending also over the opening of the ash-pit.

The fire-doors serve the purpose of supplying fresh fuel to the fire, as well as regulating the uniformity and completeness of the combustion. They should be large enough to perform this work successfully and in the shortest time, as the open fire-door always allows a large volume of cold air to enter into the furnace, thereby materially reducing the temperature of the fire as well as straining the boiler. All the different forms of fire-doors have the one object of doing the

work quickly. Some swing, for this purpose, horizontally in one or two parts, while others swing vertically with counter weights or rachet-stops, to keep them balanced or open. A fastening, or stop, is nearly always provided to keep the door in fixed position, even while the ship rolls in a seaway.

Fire-doors are nearly always made with double thickness, with a removable inner-plate that takes the brunt of the furnace heat. Both plates are usually perforated to allow a small amount of air to enter above the fire.

Ash-pit doors serve the purpose of regulating the draft to the under side of the grate. Not being exposed to any direct radiating heat, they are usually made of a single thickness of sheet steel. They are removable, and swing on horizontal round iron bars that allow them to be kept open at any desired degree between the extreme positions. The round bars rest in strong lugs on each side of the opening, and serve also for the support of the heavy firing tools that are used for the cleaning of the fires from the under side of the grate.

235. What are the use and construction of the grate and grate bearers?

The grate is constructed for the support of the burning fuel. It must be strong in order to support the weight and be sufficiently durable to stand the heat of the burning fuel. It must let in from below the necessary supply of air for the combustion in uniformly distributed quantity, and for this purpose is composed of a large number of long bars of wrought or cast iron, arranged into the form of a gridiron. The bars are fixed at regular spaces, leaving narrow slits of the required width between them. With cast-iron bars this form is secured by lugs cast on, while with wrought-iron bars the spacing is secured by distance pieces riveted or bolted between them or by grooves in the bearers.

With deep grates the bars must be made heavy and deep in the flange in order to prevent bending, and for this reason a sub-division in two or even three parts is frequently made. These several sections are supported at their ends by special bearers, running across beneath the grate. Under the heat of the fire the bars expand longitudinally quite perceptibly; consequently they should fit with sufficient clearance to allow this action, or should leave one end of each bar supported on an incline.

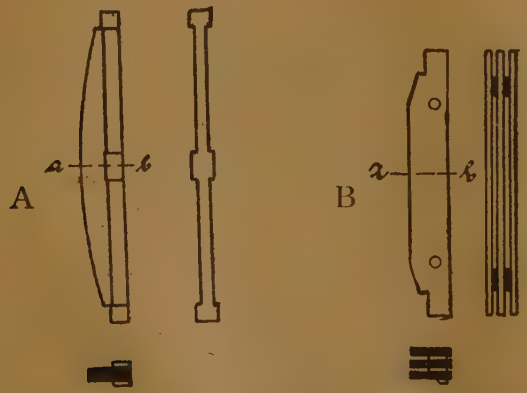

FIG. 73. Two Styles of Grate Bars Used in the Furnaces of Marine Boilers. A is a cast-iron grate, with lugs for spacing; B, a wrought-iron grate, with thimbles between bars.

Bearer bars should be sufficiently strong to carry the heaviest possible load without deflection. They find their support, in turn, from strong lugs on the side of the furnace.

The support of the grate-bars on the front is sometimes provided by the dead plate of the furnace front, while the rear end rests on the bridge-wall structure, or on bearers, as the construction of the boiler demands. The bridge wall, where fitted, separates the furnace from the combustion chamber, and offers above it only a contracted opening that seems to

produce a more direct contact and intermingling of gases and air for more complete combustion.

The bridge-wall structure below the grates is air-tight, and prevents the air in the ash-pit from entering into the combustion chamber. For certain forms of boilers a special receptacle for the ashes and clinkers has to be provided in the bottom of the ash-pit.

This is the ash-pan, usually riveted together from light steel plates and angles, well fitted to the side and back of the ash-pit and sloping up in the front, to the fire-room floor for convenience in removing the ashes.

236. What are the use and construction of the smoke-boxes and smoke-stack?

The smoke-boxes are an extension of the uptake and lead the hot gases to the stack.

With several boilers discharging into one stack, the smoke-boxes are necessarily made in complicated form for securing a good, easy lead of the gases, while offering the least resistance to their passage.

They are usually constructed of light steel plates and angles in double thickness, with dead air-space between, or are covered with insulating material to keep the radiation of heat into the fire-room as slight as possible.

With certain systems of forced draft they are used for accommodation of superheaters, or air-heaters, or hot-air exhaust fans. They are sometimes provided with dampers for allowing regulation of the draft power of the smoke-stack in its effect upon the particular boiler used. Frequently special supports are needed for holding up the smoke-boxes. Careful allowance of expansion should always be made in these supports.

The smoke-stack provides for carrying off the gases into the outside air. With forced draft it need be no higher than is

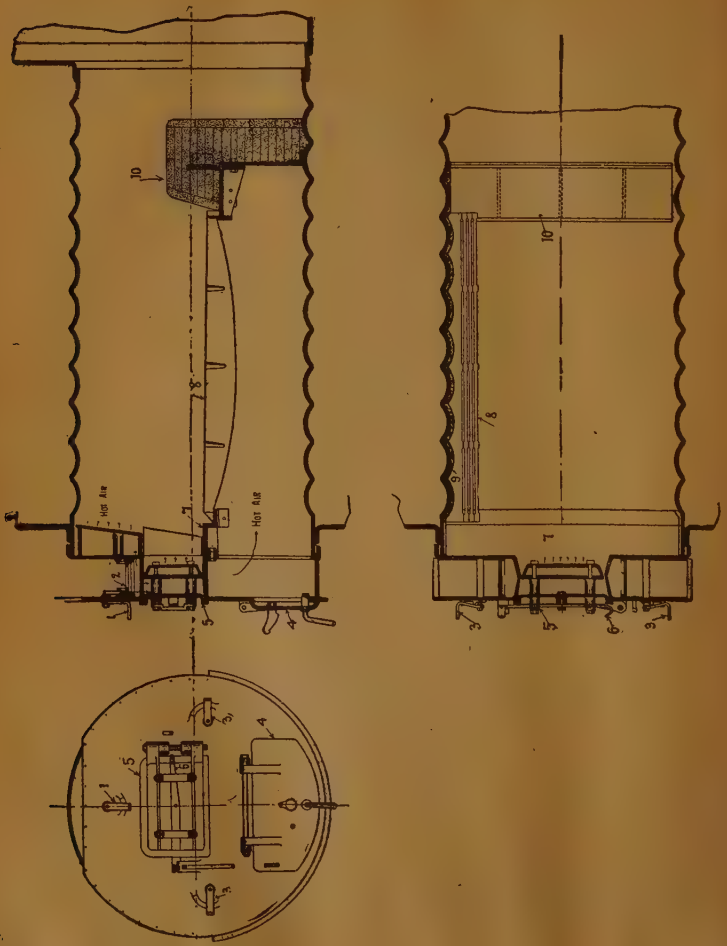

FIG. 74.—Furnace Fittings for the Howden Draft. The parts shown are: handle to move sliding gate, and admit air above the grate (1); sliding gate (2); handles to the butterfly valve admitting hot air to the ash pit (3); ash-pit door (4); furnace door (5); latch to keep furnace door open while firing (6); dead-plate (7); grate bars (8); side plate with fire-brick filling to make air-tight joint (9); bridge wall (10).

(See, also, Fig. 152.)

desirable for appearance of the ship, but with natural draft a high stack increases the draft in the boiler. Stacks are constructed with round or elliptical section, generally in two thicknesses, which have an air-space between them. By allowing the air from the fire-room to circulate through this space the outside shell is kept cool, and with the assistance of paint can more readily withstand atmospheric action.

With heavy stacks provision is made to support their weight from the decks, when a suitable expansion connection has to be made to the smoke-box. The stack is held in place by guys, running from the deck nearly to the top of the stack. On firing up, with consequent expansion of the stack, they have to be adjusted to hold the stack without straining.

The opening of the stack in wooden top decks is usually made with large clearance, the edges of which have a high iron coaming. The coaming is overlapped by a conical umbrella, fitting tightly around the outer stack to prevent rain from entering the opening. At the top of the stack are eye-bolts to allow access for painting or repairs.

Frequently provision is made for a cover, or hood, over the top of the stack, to prevent rain from entering the top in times of laying up.

RULE II, 21.—All boilers, except flash boilers, shall be supplied with at least one reliable water gauge and at least three gauge cocks attached directly to each boiler. When the gauge glass and gauge cocks are connected to the boilers by a water column there shall be three additional gauge cocks inserted in the head or shell of boiler. The lower gauge cocks in boilers more than 48 inches in diameter shall be not less than 4 inches above the top of the flues, tubes, or combustion chambers. In boilers less than 48 inches in diameter the lower gauge cock shall be not less than 2½ inches above the top of the flues, tubes, or combustion chambers. A gauge glass shall be considered a reliable water gauge, and a float such as used on western river steamers shall be considered on such boilers as a reliable water gauge: *Provided*, That when water-tube boilers have an efficient water column connected to the steam drum of said boiler at the top and the water manifold at the bottom, and such water column has a gauge glass and three gauge cocks fitted to same, and also is fitted with a valve or stopcock, both at top and bottom where the column is connected to the boiler, no gauge cocks shall be required in the head or shell of the drums of such water-tube boilers.

Double-end boilers shall have at least three gauge cocks and one water glass at each end.

In vertical boilers or boilers of the water-tube type the location of the lowest gauge cock shall be determined by the local inspectors. (Sec. 4418, R. S.)

RULE II, 22.—All boilers or sets of boilers shall have attached to them at least one gauge that will correctly indicate a pressure of steam equal to 80 per cent of the hydrostatic pressure applied by the inspectors. (Sec. 4418, R. S.)

CHAPTER TEN.

OPERATIVE APPLIANCES OF STEAM BOILERS HAVING TO DO WITH THE STEAM.

237. What are the appliances that concern the steam?

(1.) Steam-gauge.
(2.) Safety-valve.
(3.) Stop-valve and whistle, or syren-valve.

FIG. 75.

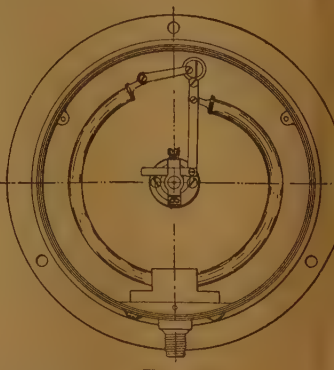

FIG. 76.

FIG. 75.—Single-tube Steam-gauge.
FIG. 76.—Double-tube Steam-gauge.

238. What are the use and construction of the steam-gauge?

The steam-gauge indicates the pressure of the steam in the boiler above the atmospheric pressure expressed in pounds per square inch. Two styles of gauges are in use, one em-

RULE VIII, 9.—It shall be the duty of both the hull and boiler inspectors to be present when the boiler is being tested by hydrostatic pressure, and the hull inspector, as well as the boiler inspector, shall observe and note the indication upon the gauge.

It shall be the duty of both the hull and boiler inspectors to examine all pumps, hose, and other fire apparatus and to see that the hose is subjected to a pressure of 100 pounds to the square inch, and that the hose couplings are securely fastened in accordance with these rules. (Secs. 4405, 4417, 4418 R. S.)

ploying a single curved tube, the other a double curved tube of oval section. By having the steam pressure on the inside and the atmospheric pressure on the outside, a change of curvature of the tube takes place, which is used to indicate the difference between the two pressures. The change of curvature is transmitted by delicate gearing to a pointer which indicates the pressure on a circular dial. The whole is enclosed in a circular brass case with glass front and connected by a small tube of some length to the steam-space of the boiler. As a high temperature would be apt to derange the delicate mechanism, a loop or bend is arranged in the pipe, which, being quickly filled with condensed water, protects the gauge against direct steam heat.

On large boilers frequently two gauges are fitted in order to serve as checks on one another for securing correctness. Being somewhat sensitive and easily deranged, they should at regular intervals be compared with a standard gauge.

239. What are the use and construction of the safety-valve?

The safety-valve prevents the steam from exceeding a certain prescribed working pressure by allowing the excess

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RULE II, 28.—On all boilers built after July 1, 1896, a stopcock or valve shall be placed between all check valves and boilers, and between all steam and water pipes and the boiler.

Where the thickness of the material in the boiler or drum, or the heads thereof, is not less than one-half inch, or where such boiler drum, or head thereof has been reinforced by having a pad or flange riveted on the same, to make the thickness not less than one-half inch, pipes or fittings of 2 inches in diameter or under may be screwed directly into the same. Where steam or feed pipes of 2 inches in diameter or under are screwed into the boiler, the stop valve shall be connected to the boiler by as short a nipple as it is possible to use, nipples to be of extra-heavy thickness.

All boiler connections of over 2 inches in diameter, except the connections for safety valves, shall be permanently flanged and bolted directly to the boiler. Where the connecting point on the boiler is of circular form, distance pieces shall be allowed in order to square the point of attachment of the flanged fittings, but no such distance piece shall be allowed to exceed 8 inches in length on its shortest side.

Cast-steel flanged fittings, when conforming strictly with the requirements for steel castings, may be used for the purpose of connecting main and auxiliary stop valves, and other steam outlets, including safety valves, distance from axis of outlets of such fittings to point of connection with boiler to be as short as practicable.

All valves shall bear the trade-mark of the manufacturer, which shall guarantee the uniform thickness of the walls of the valve chamber.

of steam to escape into the atmosphere. For this purpose its valve is held down to its seat by weights or springs, so adjusted as to equal the prescribed total pressure caused by the steam bearing against the under side of the valve.

The valve must lift these weights, or springs, sufficiently to allow all the excess of steam to escape. The weight used on a safety-valve is arranged on the long end of a lever that bears upon the valve spindle, only a short distance from the fulcrum. This arrangement needs only a comparatively small

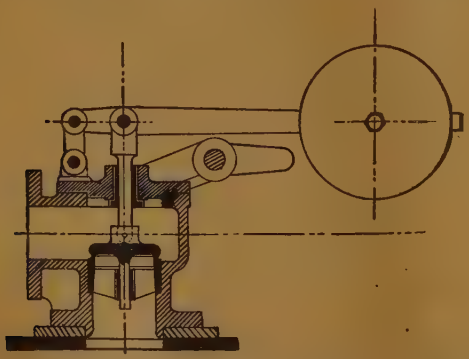

FIG. 77.—Section of Standard Weight and Lever Safety Valves.

weight, but is objectionable from the fact that it can be used only with a horizontal position of the lever, as found on river

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RULE II, 28.—*Continued.*

All such valves of 3 inches and over shall also be stamped with the number of pounds pressure of steam the manufacturer guarantees them to stand.

The manufacturer of all such valves and fittings shall file with the Supervising Inspector General a certificate duly sworn to that all valves and fittings furnished by them for use on boilers of steam vessels comply with the requirements of the foregoing rule.

After July 1, 1911, local inspectors shall refuse to allow the use of any such valves or fittings on boilers of steam vessels until notified by the Supervising Inspector General that such certificate is one file in his office. This shall not apply to valves and fittings installed previous to July 1, 1911.

Screw bonnets on cast-iron are positively prohibited. All valves over 2 inches in diameter shall have bolted bonnets or covers. The necks of the valves shall be extra heavy and as short as practicable. Where valves of less than 2½ inches in diameter are connected directly to the boiler, they shall be of cast steel, hard brass, or bronze.

All pipe fittings of more than 3 inches internal diameter shall be subjected by the manufacturer to a hydrostatic test of three and one-half times the pressure to which they will be subjected in service.

boats. Under an inclination of the boiler the leverage of the weight decreases, and it is for this reason that the boilers in seagoing vessels employ springs to hold down the safety-valves. These springs are usually encased and locked up, to prevent any tampering by unauthorized persons. The valve itself should be securely guided to prevent jamming or derangement.

To avoid a noisy vibration of the valve a lip is cast on it

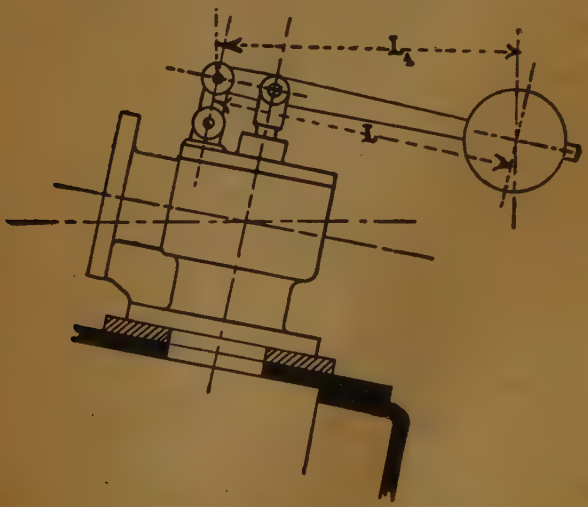

FIG. 78.—Diagram of a Weight and Lever Safety Valve, showing the decrease of the weight's effect, as the result of incline in a heavy sea.

that forces the steam into a downwardly deflected path, and keeps the valve off its seat, until the pressure has fallen sufficiently to allow it to be once more closed by the spring. Large valves must have considerable lift to give full opening, but it is considered preferable to arrange the same area in several smaller valves with less lift. To make sure that the valve does not stick, a hand-lifting arrangement is usually provided in form of a lever that takes hold of the spindle.

The safety-valve must be in direct communication with the steam-space and have an easy lead to the escape pipe to take the excess of steam into the outside air.

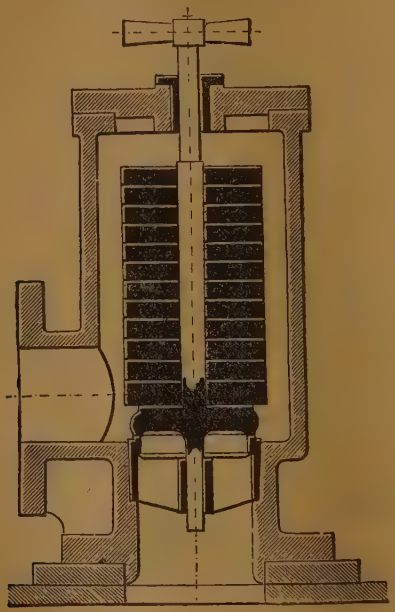

FIG. 79.—Direct Weighted Safety-valve, suitable for low pressures and small boilers. As shown, the spindle or valve stem carries a number of perforated lead discs, which serve to retain the valve on its seat.

240. What are the use and construction of the steam stop-valves?

The steam stop-valve regulates, or prevents, the discharge of steam from the boiler. The valve for this purpose can be

RULE II, 28.—*Continued.*

Valves and fittings of 3 inches and under may be connected by screw threads at their in termediate joints in pipe lines, but at point of connection with boiler all valves and fittings over 2 inches diameter shall be flanged and properly secured by bolts, studs, or rivets, and no fitting shall be of greater length than specified by the "Manufacturers' Standard."

Cast nozzles shall not be used when exposed to the direct action of the fire.

held open or closed by a screw spindle, passing outside of the casing through a stuffing box, for operation by a hand-wheel.

The angle valve is the form most frequently chosen for stop-valves, and the steam pressure is usually on the under side of the valve, thus assisting in the opening. The screw-

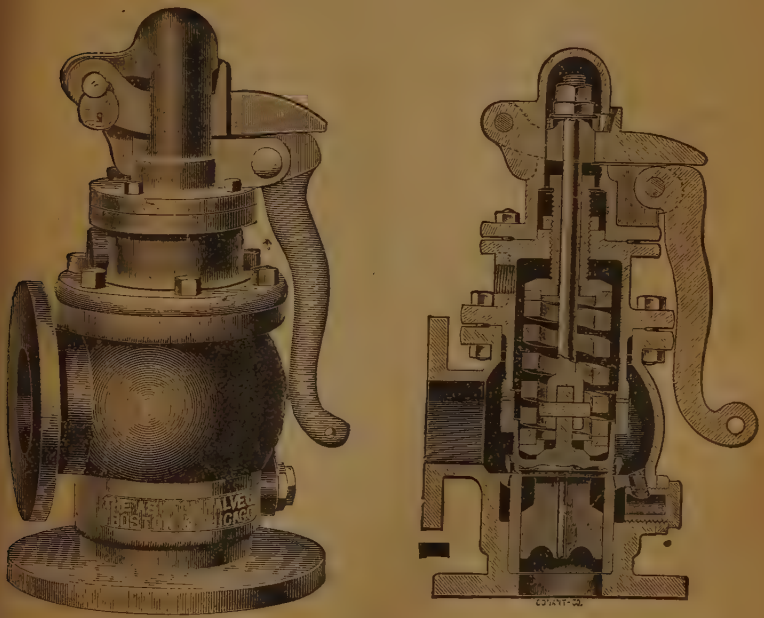

FIG. 80.—Exterior and Sectional Views of a Spring Pop Safety-valve. A spring of known strength, whose tension is adjustable to desired pressure, holds the valve upon its seat. By the lever attached to the valve stem, however, the valve may be raised, allowing the steam to blow off, whenever desired.

thread on the spindle of large valves is usually on the outside of the stuffing box, and is carried in a yoke strong enough to resist the full pressure on the valve, without deflection.

In a battery of boilers the main spindle is frequently independent of the valve, and hollow, to allow a secondary sliding

spindle, connected to the valve, to pass through it. The stop-valve acts, then, in the manner of a check valve, which closes automatically, if the pressure in the pipe is higher than in the boiler. This may prove a great safeguard in case of accident to one of the boilers. To work the auxiliary machinery, when the main engine is standing, an auxiliary smaller stop-valve is frequently fitted, in order to allow more convenient handling

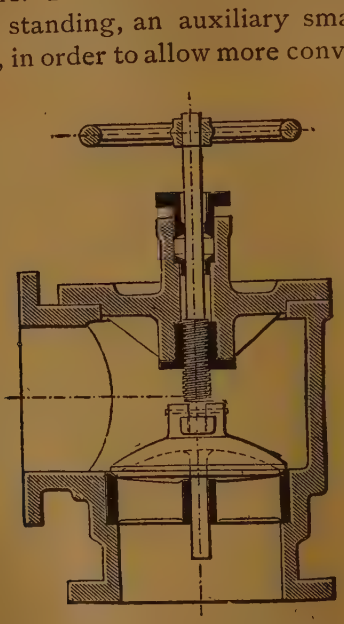

FIG. 81.—Section of an Angle Stop-valve.

of the smaller amount of steam required. A special stop-valve is on the whistle, or siren-valve, which allows the steam to enter the whistle, or siren. It is usually of the self-closing type, working under the influence of a spring on the valve. Its sliding stem is usually actuated by a lever, with rope connection to the pilot house. It should be so arranged that no condensed water can lodge in its rather long pipe, such being always drained into the boiler.

The whistle produces its noise by the vibration of a stationary cylinder, under the impact of the steam, while in the siren the passing steam rotates a little slotted wheel, which, in its

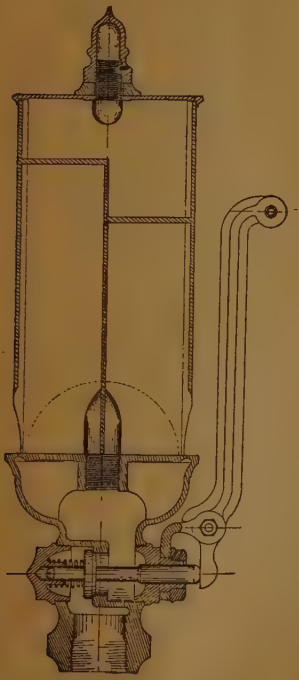

FIG. 82.

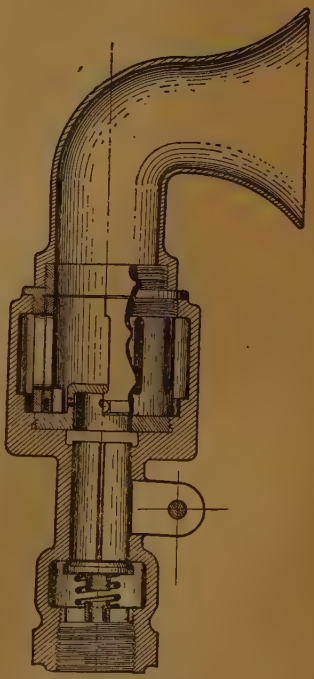

FIG. 83.

FIG. 82.—Section of a Steam Whistle and Valve.

FIG. 83.—Section of a Steam Siren.

passage, opens and closes narrow slots in the casing, thereby producing the noise.

To prevent the carrying of water into the steam-pipes and machinery, the stop-valves usually do not open directly into

the steam-space, but have an internal pipe extension. This pipe collects the steam from all parts of the boiler, through a large number of narrow slots on its upper side. As the area of these slots is large, the probability of priming is small. Furthermore, the shape of the openings has a straining action on the steam.

RULE II, 18.—The area of the segment of a head to be stayed shall be that surface contained within a line drawn 3 inches from the inner circle of the head and 2 inches from the tubes or flues.

The maximum stress allowable on flat plates supported by stays shall be determined by the following formula:

All stayed surfaces formed to a curve the radius of which is over 21 inches, excepting surfaces otherwise provided for, shall be deemed flat surfaces.

$$\text{Working pressure} = \frac{C \times T^2}{P^2}$$

Where T = thickness of plates in sixteenths of an inch.
P = greatest pitch of stays in inches.
C = 112 for screw stays with riveted heads, plates seven-sixteenths of an inch thick and under.
C = 120 for screw stays with riveted heads, plates above seven-sixteenths of an inch thick.
C = 120 for screw stays with nuts, plates seven-sixteenths of an inch thick and under.
C = 125 for screw stays with nuts, plates above seven-sixteenths of an inch thick and under nine-sixteenths of an inch.
C = 135 for screw stays with nuts, plates nine-sixteenths of an inch thick and above.
C = 175 for stays with double nuts, having one nut on the inside and one nut on the outside of plate, without washers or doubling plates.
C = 160 for stays fitted with washers or doubling strips which have a thickness of at least .5 of the thickness of the plate and a diameter of at least .5 of the greatest pitch of the stay, riveted to the outside of the plates, and stays having one nut inside of the plate and one nut outside of the washer or doubling strip. For T take 72 per cent of the combined thickness of the plate and washer or plate and doubling strip.
C = 200 for stays fitted with doubling plates which have a thickness equal to at least .5 of the thickness of the plate reinforced, and covering the full area braced (up to the curvature of the flange, if any), riveted to either the inside or outside of the plate, and stays having one nut outside and one inside of the plates. Washers or doubling plates to be substantially riveted. For T take 72 per cent of the combined thickness of the two plates.
C = 200 for stays with plates stiffened with tees or angle bars having a thickness at least two-thirds the thickness of plate and depth of webs at least one-fourth of the greatest pitch of the stays, and substantially riveted on the inside of the plates, and stays having one nut inside bearing on washers fitted to the edges of the webs that are at right angles to the plate. For T take 72 per cent of the combined thickness of web and plate.

No such flat plates or surfaces shall be unsupported at a greater distance than 18 inches.

EXAMPLE.

Required the working pressure allowable for plate five-eighths of an inch thick, with doubling plate seven-sixteenths of an inch thick, stayed 14-inch by 14-inch centers:

$$\text{Working pressure} = \frac{200 \times 149.81}{196} = 152 \text{ pounds.}$$

Plates heated for working shall be annealed afterwards.

Constant for brace rivets with substantial heads shall be the same as stay bolts fitted with outside nuts. (Sec. 4418, R. S.)

CHAPTER ELEVEN.

OPERATIVE APPLIANCES OF STEAM BOILERS HAVING TO DO WITH THE WATER.

241. What are the appliances that concern the water?

(1.) Water-gauges, test-cocks and fusible plug.
(2.) Feed-check and internal pipe.
(3.) Salinometer cock.
(4.) Bottom blow valve.
(5.) Surface blow valve.

242. What are the use and construction of the water-gauges, test-cocks and fusible plug?

Water-gauges and test-cocks have the important duty of indicating the water-level in the boiler.

The water-gauge shows the level in a glass tube, leaving unobstructed connection at top and bottom to the steam-space and the water-space. In each of these connections is a cock or valve for allowing the glass tube to be disconnected from the boiler. As the glass is frequently broken and has to be replaced, an automatically closing device is often added, which

RULE II, 26.—Feed water shall not be admitted into any marine boiler at a temperature less than 100° F., and every such boiler, excepting donkey boilers, shall, after October 31, 1909, have an independent auxiliary feed appliance for supplying said boiler with water in addition to the usual mode employed, which auxiliary feed shall enter the boiler through an opening and a fitting which are entirely independent of the fitting and opening for the main feed. (Sec. 4418, R. S.)

RULE II, 28.—When evaporators, feed heaters, and separators are constructed of cast iron possessing a tensile strength of not less than 20,000 pounds per square inch, the shells being cylindrical and end flat or convex, the casting sound and of uniform thickness, the working pressure shall not exceed that found by the following formulas:

Flat Surface: $P = \frac{20{,}000 \times T^2}{D^2}$

Cylindrical shell: $P = \frac{3{,}500 \times T}{D}$

$T = \sqrt{\frac{P \times D_2}{20{,}000}}$

$T = \frac{P \times D}{3{,}500}$

Where P = working pressure per square inch in pounds. T = thickness in inches.

contributes greatly to the ends of convenience and safety. An extra cock or valve on the bottom connection allows the blowing out of any obstructions that may have accumulated in the tube connections.

FIG. 84.—Section of a Type of Combined Water Column and Low-water Alarm, showing connections to steam gauge and boiler space.

Guard rods are fitted around the glass to prevent breaking by blows from the outside. Steam-tight joints are made by rubber washers over the glass at top and bottom.

To prevent irregular movements of the water-level in the glass, under the influence of local currents in the water of the boiler, the water-gauge is not usually attached directly to large boilers. It is attached rather to a large pipe or drum, having direct connection to the steam and water spaces well up and well down, away from outlets or inlets, securing thereby a much steadier level and much clearer indication of its position. When a low-water alarm is considered necessary the floating ball that usually actuates the alarm whistle or bell is arranged in this pipe, or in an extra enlarged section of it, that provides also for the attachment of water-gauge and test-cocks.

The test-cocks serve for the indication of the water-level i the gauges should fail. They are

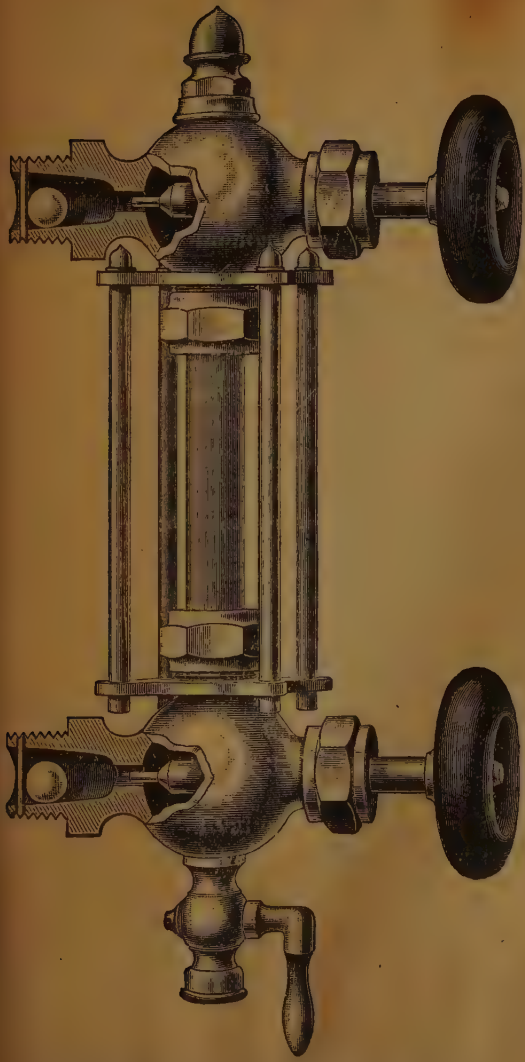

FIG. 85.—Type of water gauge glass equipped with self-closing ball valves. The water glass in this instrument is protected by four guards.

RULE II, 28.—*Continued.*

Provided, 1.—That the thickness of ends of evaporators, feed heaters, and separators shall be not less than three-eighths of an inch. 2.—That to the resultant thickness obtained by the formula given above there shall be added, for cylinders having an inside diameter of 1 inch to 6 inches inclusive, one-fourth of an inch; for cylinders having an inside diameter of over 6 inches to 15 inches inclusive, one-eighth of an inch.

D = diameter inside in inches. When the pressure is to be determined for a part of a flat surface which is a square, or rectangle in the flat surface formula, the value of D used shall be the diagonal of the square or rectangle, and when the ends are bolted to the shell the value of D used shall equal the diameter of the bolt circle.

All flanges shall be substantial, and there shall be a good fillet all around the root, and when the ends and shell are cast solid there shall be a good and substantial fillet inside all around.

The bolts or studs for the ends or doors shall not have a greater stress than 6,000 pounds per square inch, and the size of bolts or studs shall be not less than three-fourths of an inch in diameter.

Evaporators shall be provided with an efficient safety valve of approved type, same to be set to blow at 10 pounds pressure, and it shall be the duty of the engineer in charge of the vessel to see that such valve blows off at least once in 30 days. (Sec. 4418, R. S.)

usually three in number, the middle one being at the usual water-level of the boiler; the upper one about 4 to 6 inches above the level, and the lower one about three or four inches above the highest point of the heating surface.

The test-cocks are made in different forms, cocks or valves sometimes self-closing by spring pressure or weights.

Another form of safety device is the fusible plug. This is a plug of Banca tin, or some composition that melts under the heat of the fire if uncovered by the water. It is usually fitted inside of a composition plug, threaded to screw into the boiler shell just above the fire. The steam that rushes out of the opening, as the plug melts, deadens the fire, and so helps to prevent damage to the exposed surfaces in the furnace, combustion chamber or tubes.

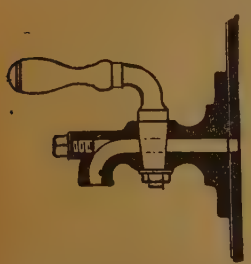

FIG. 86.—Section of a Boiler Try-cock. Three of these cocks are placed in the shell of the boiler; one at the water level, a second above, and a third below.

243. What are the use and construction of the feed-checks and internal feed arrangements?

The feed check-valve ensures the result that no water fed into the boiler can be forced out again by the steam pressure through lack of tightness in pipes or pump discharge valves. It is arranged, for this purpose, in form of an angle automatic check-valve, whose lift is limited by an independent stem. The position of the valve in its casing should be well below the discharge opening into the boiler to prevent any back-flow of the water from striking the valve sideways

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RULE II, 10.—Local boards shall report forthwith to their supervising inspectors in detail all accidents of a serious character—such as collisions, founderings, sinkings, fires—and all other casualties of interest to or affecting the steamboat service in their respective districts (Sec. 4405, R. S.)

RULE II, 16.—No marine boiler shall be used without having proper auxiliary appliances for supplying said boilers with water.

and keeping it open by jamming. The valve should be guided well to secure an easy lifting and seating.

244. Of what use is the salinometer cock or valve?

It is used to take a sample of the boiler water in order to determine the amount of salt held in solution.

245. What is the use of the bottom blow valve?

It is used to blow out impurities, mud, etc.

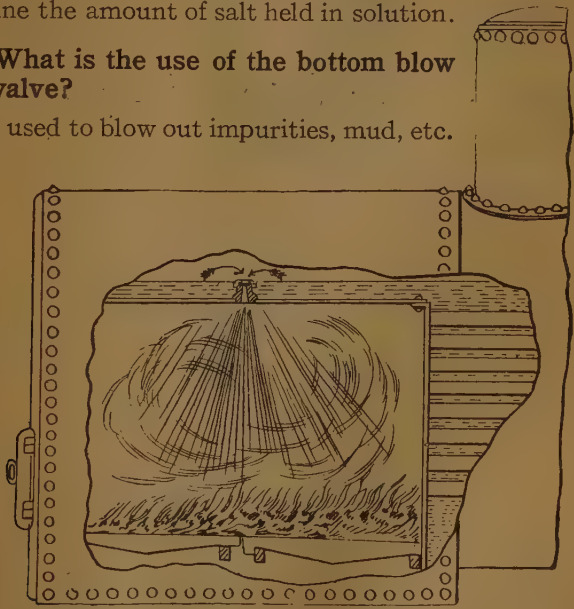


FIG. 87.—Arrangement of a Fusible Plug in the Crown Sheet of the Furnace, showing effect of melting the fusible metal, owing to unusual temperature.

NOTE.—To enable the check-valve to be overhauled, modern practice requires that a stop-valve or stop-cock be fitted between the boiler and feed check. Two checks are nearly always fitted to keep the main and auxiliary feed entirely independent, and secure thereby almost absolute certainty against a complete breakdown of the feed arrangements. To prevent an injurious effect upon fire-tube boilers by the cold feed-water, an internal feed-pipe discharging through a large number of small holes, is employed for more complete intermingling with the boiler water. This pipe should be so arranged that it is always full of solid water, without steam pockets, as the condensation of this steam by the cold feed-water produces the effect known as "water hammer" at every stroke of the pump. This soon proves very destructive to pipe and fastenings. All feed connections and valves should be heavy and strong, as they have to perform severe service. Special appliances are often provided in water-tube boilers to secure a more uniform feeding that can be realized by the water-tender. A special valve, actuated by a float in the top drum, stops the feed, if the water-level rise above the normal and admits more feed if the level fall below it. With a battery of water-tube boilers, such feed regulators, if of reliable and substantial construction, prove of great assistance to the engineer.

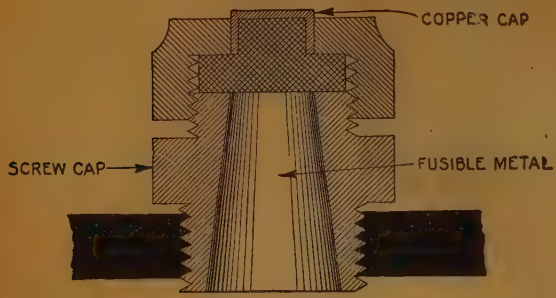


FIG. 88.—Bailey fusible plug. The body of the plug is permanently fixed. A screw cup holds the fusible disc in place. The upper part of the disc is protected by a copper cap which is intended to prevent the water coming in contact with the soft metal, thus maintaining its normal point of fusion. Plain or ordinary plugs do not have the copper cap to protect the fusible disc.

RULE II, 20.—Fusible plugs for use in boilers of steam vessels under the jurisdiction of the Steamboat-Inspection Service shall be made of a bronze casing with the bore tapering continuously and evenly from end to end, and filled from end to end with tin not less than 99.7 per cent pure and to contain not more than .1 per cent of lead and not more than .1 per cent of zinc. The small end of the bore may be countersunk not more than one thirty-second of an inch in depth and width, but no recess, thread, or cavity other than this countersink shall be allowed.

Fusible plugs, except those which are hereafter provided for, shall have an external diameter of not less than three-fourths of an inch pipe tap, and the filling shall be at least one-half of an inch in diameter at the smaller end and shall have a larger diameter at the opposite end of the plug: *Provided, however*, That all fusible plugs fitted in boilers carrying a steam pressure exceeding 150 pounds to the square inch may be reduced at the smaller end of the filling to five-sixteenths of an inch in diameter.

Every boiler other than boilers of the water-tube type shall be fitted with at least two fusible plugs as described above and located as follows:

Upright boilers shall be fitted with two fusible plugs of an external diameter of not less than three-eighths of an inch pipe tap, the filling to be at least one-fourth of an inch in diameter at the smaller end and shall have a greater diameter at the opposite end. The fusible plugs shall be located in separate tubes not more than 2 inches below the lowest gauge cock.

Externally heated cylindrical boilers, with flues, shall have one plug in the top of the upper flue, not more than 4 feet from the back end of the flue, and shall also have a plug fitted to the shell of the boiler immediately below the fire line and not less than 4 feet from the front end: *Provided, however*, That when the flues are not more than 6 inches in diameter fusible plugs of not less diameter than three-eighths of an inch pipe tap may be used in such flues.

Fire-box, Scotch, and other types of shell boilers not specially provided for, having a combustion chamber common to all furnaces, shall have two plugs fitted to the crown sheet of the combustion chamber at or near the center of the crown sheet and not more than 12 inches apart. Boilers fitted with separate combustion chambers shall be fitted with a fusible plug in the center of the crown sheet of each chamber.

Boilers of types not herein provided for shall be fitted with at least two fusible plugs of such dimensions and located in such parts of the boiler as will, in the judgment of the local inspectors, best meet the purposes for which they are intended.

Fusible plugs shall be renewed after six months of service, and the inspector of boilers shall assure himself at each annual inspection by personal examination and by testing the ends of the filling by filing to determine its condition that the plugs are in good and serviceable condition.

Fusible plugs shall be so fitted that the smaller end of the filling is exposed to the fire and shall be at least 1 inch higher on the water side than the plate or flue in which they are fitted.

Notwithstanding anything which may be contained in this rule, fusible plugs shall be so fitted that the end of the filling on the water end of the plug is not less than 1 inch above the dangerous low-water level.

It is fitted near the lowest point of the boiler in strong and substantial manner, and should be so arranged that it indicates unmistakably whether it is open or shut.

Frequently a handle, or spanner, is fitted in plain view of the fireman, and so arranged that it can be removed only when the valve is tightly closed.

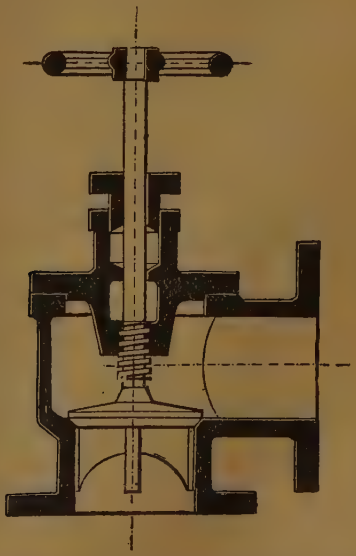


Fig 89.—Sectional View of an Automatic Angle Check Valve.

246. What are the use and construction of the surface blow valve?

The surface blow valve is fitted for the removal of impurities at the water-level, like grease, oil and scum.

It is arranged near the water-level and carries an internal pipe fitted to it that ends in a flat pan directly below the water-line. With dirty feed-water it may prove a help to check priming and keep the water-gauges clear.

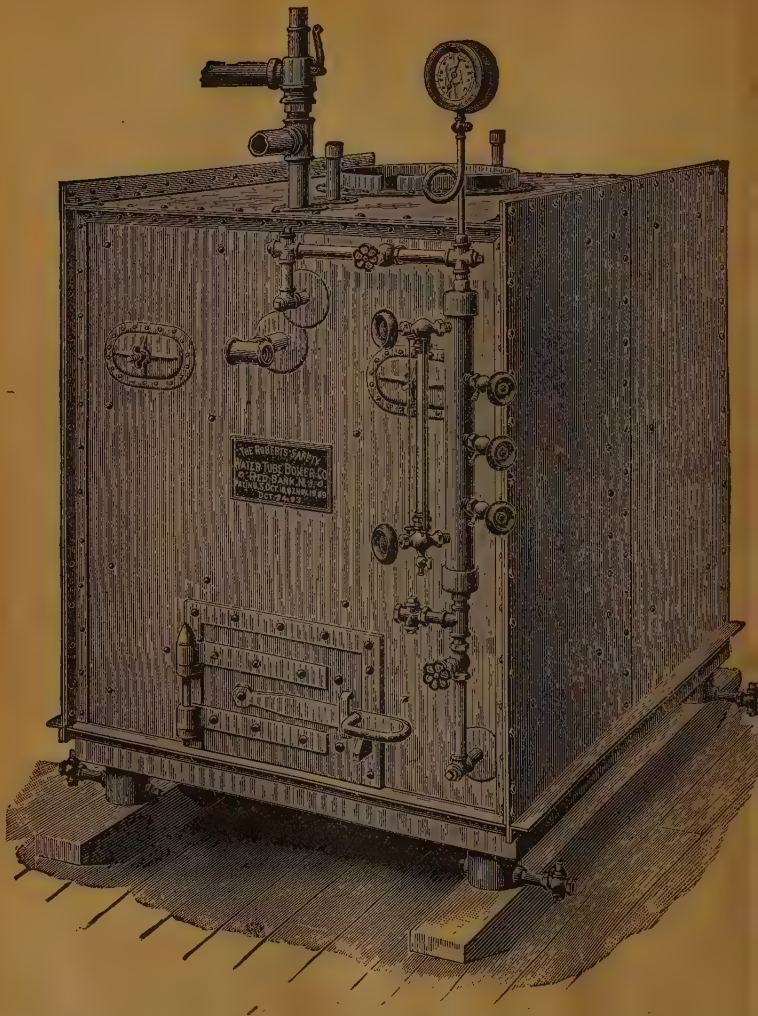


FIG. 90.—Outside Elevation of the Roberts Boiler (Figs. 51 and 52), shown in casing, with steam and water attachments.

PART THREE.

THE MARINE STEAM ENGINE.

CHAPTER TWELVE—GENERAL TYPES AND CHARACTERISTICS.

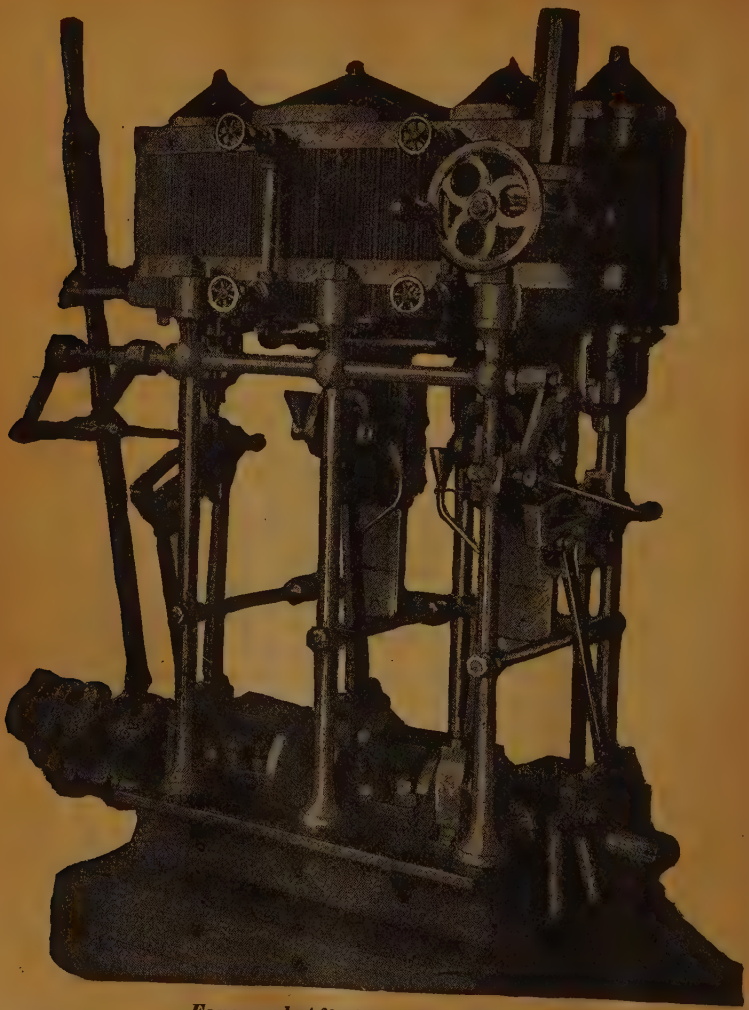
CHAPTER THIRTEEN—STATIONARY PARTS, I: CYLINDERS, ETC.

CHAPTER FOURTEEN—STATIONARY PARTS, II: BED PLATES, ETC.

CHAPTER FIFTEEN—MOVING PARTS, I: VALVE-GEAR, ETC.

CHAPTER SIXTEEN—MOVING PARTS, II: PISTON, PISTON ROD, ETC.

CHAPTER SEVENTEEN—OPERATIVE DETAILS OF A MARINE ENGINE.



Fore and Aft Compound Engine

Designed by F. D. Graham for 35′×7′ launch ***"Stornoway"***; illustrating the accessibility due to the open column type frame; also, self contained ball thrust bearing. Cylinders 3½, and 8, by 6; cylinder ratio 1 : 5.23; shifting link motion with adjustable arm on *h. p.* gear; piston valves; mahogany cylinder lagging with nickel plated bands and cylinder head bonnets. The bearings are proportioned for high speed heavy load service.

CHAPTER TWELVE.

GENERAL TYPES AND CHARACTERISTICS OF THE MARINE ENGINE.

247. What is the fundamental function of the steam engine?

The steam engine serves the purpose of converting heat energy into mechanical work through the capacity of expansion in the steam.

248. How is the conversion of the heat energy into mechanical work effected?

The expansive power of the steam acts in a cylinder upon a movable piston, alternately in front or behind, under the influence of an automatic valve, which produces a uniform series of reciprocations of the piston.

249. How is the automatic action of the valve produced?

The automatic action of the valve is assured by making its motion dependent upon the motion of the piston, as will be presently explained, so that a certain position of the latter always ensures the same corresponding position of the former.

250. What is the action of the valve in its guiding influence?

The steam enters and leaves the cylinders by openings, or ports, in its ends, and the valve action closes or opens these ports to either the steam or exhaust pipes in regular intervals of time.

251. Is the action of the valve of a marine engine altogether automatic?

Not entirely, because a marine engine must be reversible

in order to make the ship go forward or backward, as needed.

This requires an arrangement that can change, or suspend, the connection of valve and piston.

252. What are the different periods of action of the steam in the cylinders?

In each cylinder there is a certain period of admission, of expansion, of exhaust and of compression.

253. What is the period of admission?

The period of admission is the time during which the valve allows the steam to enter the cylinder from the boiler or receiver.

254. What is the period of expansion?

The period of expansion is the time during which the steam expands, after the valve has cut off the boiler, or receiver, steam, driving the piston forward by the gradually decreasing pressure.

255. What is the period of exhaust?

The period of exhaust is the time during which the valve connects the cylinder with the exhaust pipes.

256. What is the period of compression?

The period of compression is the time during which the steam is compressed, after the valve has cut off the connection to the exhaust pipe, and before it has opened the steam pipe connection; as the piston continues to move to the end of the stroke, under its own momentum, it compresses the enclosed steam into a smaller volume, and thereby raises its pressure.

257. What is the clearance space of a cylinder?

The clearance space of a cylinder is the volume between the valve face and the piston in its extreme position.

It comprises the volume of the port and that of the space between the piston and end cover of the cylinder.

258. What affects the size of this clearance?

The clearance is affected by the size of the port, as required by the steam consumption of the engine per time unit, and by the practical consideration of making the space between the piston and the head large enough to prevent injury to the head by the piston, through wear in the bearings or through small quantities of condensed water.

259. What influence has the clearance on the steam consumption of the cylinder?

The clearance has to be filled each time with additional steam of full admission pressure, which occasions an increased consumption of steam.

260. What is piston speed?

The piston speed is the velocity of travel expressed by the number of feet that the piston covers in one minute.

261. What is the relation between piston speed and revolutions and stroke?

A certain piston speed can be obtained in two ways: by having a long stroke and few revolutions, or by having a short stroke and many revolutions.

For example, a piston speed of 400 feet per minute can be obtained in an engine of 10 feet stroke and twenty revolutions per minute, or in an engine of 2 feet stroke and 100 revolutions per minute.

262. What are the most important periods of action of the steam?

The most important periods are those of admission and expansion, since variations of their length have the most

pronounced effect on the economy of steam consumption in proportion to the work done. This was shown in Fig. 33 by the cases A and B, where the short admission and long expansion proved the most economical, limited, however, for practical purposes mainly by cylinder condensation, under great temperature changes.

263. How is it possible to secure a large expansion and keep the cylinder condensation at the same time within reasonable limits?

A large expansion can be effectively secured by having it take place in several stages, which are called compound, or double, and triple and quadruple expansion, according to the number of cylinders.

264. What are the names of the successive cylinders in which these expansions take place?

The first cylinder is called the *high pressure cylinder* and the last the *low pressure*, while the intermediate ones are called the first and second *intermediate* cylinders when there are two, as in a quadruple expansion engine.

265. Are these cylinders all of the same size?

No; the cylinders, from the high pressure up, are of increasing dimensions and volume.

266. Why does the volume of the successive cylinders increase?

The volume of the cylinders must increase successively to secure a back pressure lower than the driving pressure.

267. What is the space between two cylinders called?

The space between two cylinders is called the receiver space.

268. Into what does the steam from the last, or low pressure, cylinder expand?

The low pressure steam expands into the condenser, where the lowering of the back-pressure is realized by condensation of the steam.

269. What is the lowering of the back-pressure called?

The lowering of the back pressure in the receiver space and next cylinder is called the "*drop*."

270. Is this "drop" disadvantageous?

No; the steam expands, without doing any work, and retains its heat energy, which shows itself in superheating of the steam.

271. What are the most general ratios between the cylinders?

For compound or two cylinder arrangements the ratio between high and low pressure cylinder volumes is often 1 to 4.

For triple expansion arrangements the ratio between high and low is frequently 1 to 7.2 and between high and intermediate, 1 to 2.7.

For quadruple arrangements the ratio between high and low pressure is often 1 to 10.5 or 11.0; between high and first intermediate, 1 to 2.3, and between high and second intermediate, 1 to 5.4.

272. What different types of engines are distinguished in common practice?

Engines may be classified under several heads:

(1.) According to the style of build, as horizontal, diagonal or vertical engines, which latter may be again divided into direct or indirect acting engines.

(2.) According to boiler pressure used, as high pressure or low pressure engines.

(3.) According to expansion of the steam in one or more cylinders, as single or multiple cylinder engines.

(4.) According to propelling agent, as paddle-wheel or screw engines.

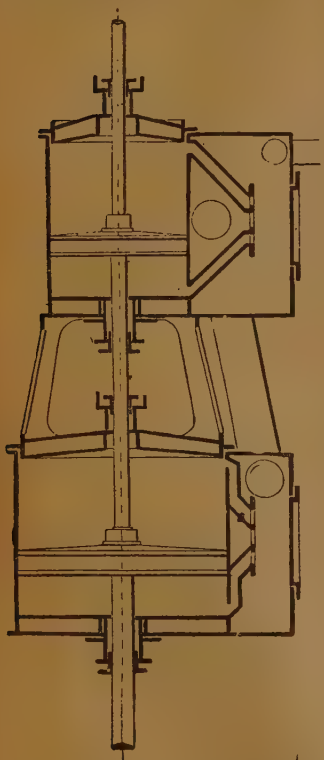


FIG. 91.—Sectional Sketch of the Cylinders of a Tandem Compound Marine Engine, showing steam connection between the two valve chests. The upper is the high-pressure cylinder, the lower, the low-pressure.

(5.) According to arrangement of the cylinders, as fore and aft, tandem or combination engines.

(6.) According to piston speed or revolutions, as high-speed or slow-speed engines.

The most common cases have, for screw propulsion, vertical direct acting engines, in single, twin or triple screw arrangements, with cylinders in tandem, or fore and aft fashion; while for paddle side wheel the single or compound beam engine finds favor, as well as, lately, the diagonal multiple cylinder direct-connected engine.

For stern wheel practice a double, single or compound horizontal direct-connected engine is almost exclusively in use.

273. What are the main characteristics of the vertical, direct-connected, multiple-cylinder engine for screw propulsion?

This highly modern type of engine is built in compound, triple and quadruple arrangement, and, in accordance with this, employs high pressure steam, up to the limit that the boilers can supply.

It runs, usually, at a fairly high number of revolutions, varying

from 80 to 400, associated with a medium or short stroke, up to between 60 and 66 inches. The valve gear is mostly of the slide, or piston, type, and reversal is effected by either link or radial valve gear.

Its build makes access to all parts convenient for lubrication, adjustment and repair. It is of strong and substantial form, self-contained on its bed plate, insuring good alignment and a smooth working engine. It is universally used for ocean-going ships, where deep draft allows a sufficient diameter of propeller. Where the diameter of the wheel is restricted by draft, or for other reasons, the twin or multiple-screw arrangement is employed, introducing, however, the disadvantage of a large number of parts and joints that are liable to prove a great source of care and trouble to the engineers.

274. What are the characteristics of the vertical walking beam engine for paddle-wheel propulsion?

The beam engine, so well known on the lakes, sounds, bays and rivers of the United States has usually only a single cylinder, with a stroke quite long in proportion to its diameter, and varying frequently between 7 and 12 feet.

Expanding the steam in a single cylinder only, it is employed with the rather low steam pressure of from 50 to 60 pounds per square inch. On account of its heavy walking beam it is best suited to run with a limited number of revolutions, varying frequently between 20 and 30.

The valve gear is almost always of the double poppet valve type, actuated by cams on a rock-shaft. To secure a variability of expansion in the single cylinder, some form of cut-off arrangement is provided, of which constructions the Sickels cut-off gear is a well-known one. Under the influence of a second eccentric, it allows the poppet valve to drop precisely by disconnecting it from the lifting rod. Reversal is effected

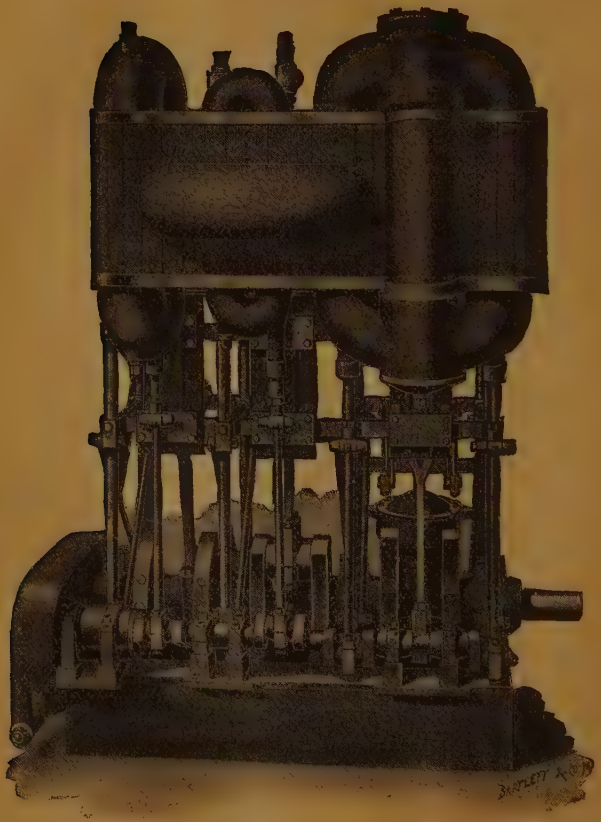


FIG. 92.—Triple-expansion Marine Engine, with gear-driven valve shaft.

by disconnecting the eccentric rods from the rock-shaft lever and giving live steam by hand on the opposite side of the piston. This entire suspension of the automatic action of the valve, which would be impossible in quick running engines, proves exceedingly handy and serviceable in the beam engine.

Where long continued backing is required, as in ferry boats, special backing eccentrics and rods are provided, which hook in when the forward eccentric rods hook out.

The support of the engine is derived from the so-called "A" frame that provides bearings for the walking beam pins at the top and for the shaft at one side, and connects to the cylinder and guides on the other side. Great size and weight concentrated on a short length and a high centre of gravity are characteristics in the beam engine that will finally cause it to be superseded by other constructions, regardless of the great popularity that it has enjoyed.

275. What are the main characteristics of the diagonal direct connected engine for paddle-wheel propulsion?

This engine is extensively used in Europe for paddle-wheel propulsion, and conveniently allows compound and triple-expansion arrangements, thereby ensuring economical use of high pressure steam.

The revolutions are usually higher than with the beam engine, averaging between 30 and 50 per minute, while the stroke is correspondingly reduced to between 5 and 8 feet. The valves and valve gears are similar to those of vertical screw engines, with link and radial gears in favor for reversing. The position in the hold of the ship allows a strong arrangement, with fairly good access to all parts.

Comparative lightness, distribution of the weight on the whole length of the engine room and a low centre of gravity seem to render this type of engine well calculated to supersede the

FIG. 93.—Direct-connected Stern-wheel Engine. Side elevation and plan of the wheel and one pair of compound cylinders.

beam engine, where draft or other restrictions make paddle-wheel propulsion desirable.

276. What are the main characteristics of the horizontal direct-connected engine for stern-wheel propulsion on Western rivers?

The Western river stern-wheel engine is generally arranged in duplicate, one cylinder on either side, connected to the outside of the wheel, on or near the guards of the boat.

It employs high pressure steam, and, in late forms, is built in tandem or cross-compound arrangement, allowing greater economy than the single expansion engines. The stroke is between 5 and 12 feet, and is large in proportion to the cylinder diameter. Due to direct connection they can be run at a somewhat higher number of revolutions than beam engines.

The valve gears of this type of engine are of manifold constructions, a form of poppet valves actuated by long cam-driven levers finding great employment; otherwise, rotating valves, common slide and piston valves are in frequent use.

The simplicity of the engine, its great accessibility and easy repairs have made it very popular for river navigation.

277. In what part of the ship are the engines placed?

For screw-engines the position is either at about the middle of the ship or at the extreme end. The former position is chosen for seagoing cargo and passenger ships, while the latter is preferred for lake cargo steamers and oil tankers, where one continuous cargo space is considered desirable. Side paddle-wheel engines are placed near the middle of the ship, but the stern-wheel engines are set at the rear, in order to follow the wheel for direct connection.

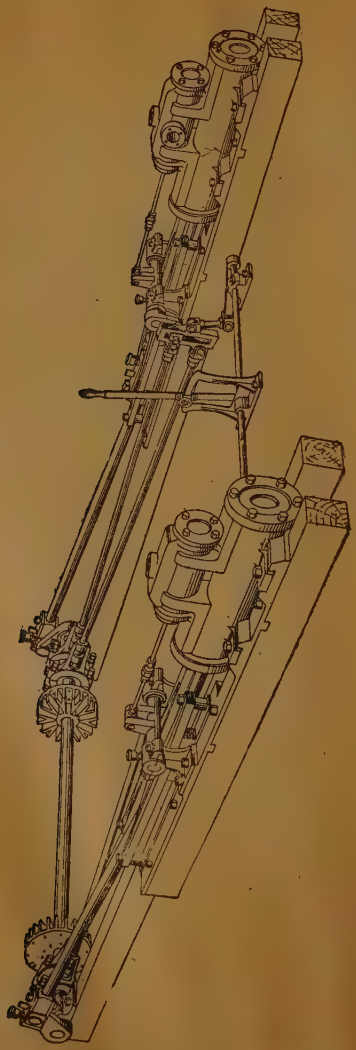


FIG. 94.—Direct-connected Stern-wheel Engine, showing general arrangement of the cylinders and driving gear, connected to the shaft of the stern paddle-wheel.

The effect upon the trim of the ship by an after-position of the machinery is counterbalanced in screw steamers only by the cargo, while in stern-wheelers the boilers are placed at a corresponding distance forward near the bow; they thus counterbalance the engines sufficiently to give the ship the proper trim, as shown in fig. 95.

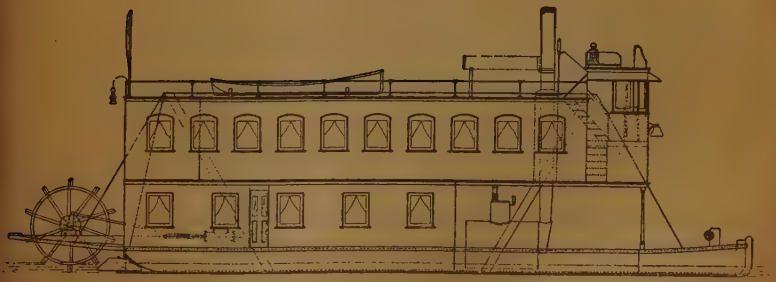


FIG. 95.—Type of Western River Boat Propelled by Stern Paddle-wheel and Direct-connected Engine, such as is shown in Figs. 93 and 94.

CHAPTER THIRTEEN.

STATIONARY PARTS OF A MARINE ENGINE, I.

THE CYLINDER AND VALVE CHEST, FRAMING AND GUIDES.

278. What are the stationary parts of the steam engine?

(1.) The cylinders and valve-chests.

(2.) The framing and guides.

(3.) The bed-plates, foundations and shaft supports.

279. What are the functions of the cylinders and valve-chests?

The cylinders provide space for the expansion of the steam behind or in front of a tightly-fitting piston.

It has openings, or ports, for the regular inlet and outlet of the steam through the guiding valve.

The valve-chests provide a separate space for the admission and the exhaust steam, which are separated through the valve. Where the ports end at the valve-chests a face is provided around them for the valve to work on.

280. What is the material generally chosen for the cylinders and valve-chests?

A good quality of cast iron is universally chosen for cylinders and valve-chests, being the material best adapted for a ready production of the many rather intricate forms and shapes that a cylinder requires.

281. Of what form is the cylinder?

The cylinder is of a round barrel-shape with flanges and stiffening bands around it. Being round, with inside pressure,

it has good strength and can be constructed with comparatively thin walls. The inside is bored to a true cylindrical surface, allowing a uniformly tight fit of the piston throughout its travel. At each end this working face is recessed to allow a certain over-running of the piston rings and more uniform wear.

282. Of what form and construction are the ports?

The ports open into the recessed ends of the cylinder bore, in a narrow slot above and below the edge of the working face, and take the form of a rectangle of great width and small depth. They are frequently curved in their advance toward the valve-chest, to secure shorter valves and smaller chests with less exposed steam surface.

The flat walls of the ports have to be efficiently ribbed and stayed to resist the steam pressure.

283. Why is the cylinder closed by removable heads at one or both ends?

The cylinder has to allow for the entering of the piston as well as finishing of the inside surface. For this reason faced flanges are provided that receive the flanges of the heads with some packing material between them. Steel bolts or studs through these two flanges complete the steam-tight connection.

In the cylinders of vertical engines the lower head is frequently cast in one piece with the cylinder casing, providing in its centre only a small opening for the fitting of the piston-rod stuffing-box, which also serves for the passing of the boring bar in finishing the working face.

284. For what purpose is a cylinder liner provided?

The wear of the piston requires a hard and close-grained working face that can be more easily secured in a separate liner than in connection with the whole cylinder casting. For

this reason a liner is pushed tightly into the cylinder, fastened with an inside flange to the bottom, and made steam-tight at the top with a shallow stuffing-box. The liner and cylinder barrel touch each other only on facing strips, leaving between them an annular space that sometimes is utilized as a steam jacket, or otherwise serves to reduce the radiation of heat from the cylinder. The liner should be always of cast iron to insure the same expansion as the cylinder casing. With different materials injury to one or the other part is apt to result.

285. How are the heads constructed?

The heads are discs of single or double thickness, with stiffening ribs for effective resistance of the steam pressure. In the centre of the heads there is an opening and facing for the attachment of piston-rod stuffing-boxes or guide sleeves. Care in the fitting of the heads should be taken to leave a certain clearance at the extreme position of the piston.

286. Of what form is the valve-chest of slide and piston-valve engines?

The valve-chests of all engines fitted with plain slide or piston-valves are commonly of a box, or cylindrical, shape usually cast with the cylinder in one piece. Covers in heads or sides allow for the introduction of the valves. Nozzles for steam and exhaust pipes establish the connection to the boiler to other cylinders or to condenser. The valve face, made flat for slide, and cylindrical for piston valves, is finished for an accurate fit of the valve, having the edges of the port opening accurately cut, to conform to the cutting-off edges of the valve. Frequently a false face, or liner, is provided that furnishes material of better wearing quality and allows more accurate finish for the port edges. Stuffing-boxes or sleeves in bottom and top act as guides for the valve stems.

287. Of what form is the valve-chest of poppet valve engines?

Poppet valve engines have generally an independent valve-box at each end of the cylinder next to the port with pipe connections, so-called side pipes, between them. Heads for the introduction of the valves and stems are arranged in convenient positions, with stuffing-boxes or guide bushings as required. The side pipes being usually of a different temperature from the cylinder, which holds and supports the valve-boxes rigidly, have a provision made for expansion that keeps the joints from suffering injury.

In beam engines this expansion is provided by the deflection of a steel plate of large diameter, connected near its centre to the valve-box, and at its circumference to the funnel-shaped flare of the side pipe.

288. What connections are usually made to the cylinders and valve-chests?

Since the condensed water must be carefully drained from cylinders and valve-chests, openings and facings in the lowest points of the cylinder heads, ports, chests and pockets, that might hold water, have to be provided for the attachment of the drain cocks and valves. To prevent injury to the castings by accidental occurrence of too high a steam pressure, openings and facings, for the attachment of safety or relief valves, are provided on the ends of the cylinders and valve-chests. Also oil-cups and indicator connections must be provided for by bosses or facings. For the connection of the cylinders and chests to the framing, or foundations, lugs are provided to transmit the thrust or weight.

289. For what purpose are the clothing and lagging fitted to cylinders and valve-chests?

Clothing and lagging the cylinders and valve-chests prevents loss of heat from the steam through radiation. For this

purpose, therefore, non-conducting materials are chosen, like mineral wool, asbestos, felt, wood, etc.

A popular arrangement is to clothe with finished mahogany in moulded staves, held and fastened by polished brass bands, while Russia iron covers over felt or wood, fastened with round-headed brass screws, make another very neat and pleasing arrangement.

290. What is the function of the framing?

The framing provides the support and rigidity of the engine. It prevents the strains of the engine from producing deformation or deflection of the parts.

291. What are the function and construction of the guides?

The slipper guides that take the reaction thrust of the connecting rod usually find their support on the framing.

They may be made independent and bolted to the framing, but if severe service is anticipated they are frequently cast hollow and arranged for cold water circulation. Some engines have a guide on each side, one for forward, the other for backing motion, while other constructions have only one guide, with backing strips, hooking over the flat slipper of the cross-head.

The flat face of the guide has to be exactly parallel to the axis of the cylinder to prevent all bending of the piston-rod.

292. How is the framing of a vertical direct-acting screw engine constructed?

The framing of the vertical screw engine consists of standards, or columns, of cast iron, cast steel or wrought steel in box, I-shaped or round sections. They support and connect the cylinders at the top with the bed-plate and foundations below.

The attachment is made by bolted flanges or large screw

nuts. The sections should possess ample strength to withstand the tension, compression or bending strains, and the standards are, for this reason, frequently connected with each other by horizontal or diagonal braces. They provide a support for the guides to take the side thrust of the cross-head.

The framing supports the hand or steam reversing gear, and the throttle and drain cock lever. In many cases the surface condenser forms part of the framing and part of the bed-plate.

293. How is the framing of the beam engine constructed?

The framing of the beam engine serves the primary purpose of giving rigidity to the engine structure by holding the cylinder in vertical position; receiving the side thrust of the cross-head and resisting the weight and bending momentum of the beam. It also helps to transmit the thrust of the wheel shaft to the hull of the ship. The two A-frames were formerly constructed of wood, but now nearly always have steel plates and angles that ensure greater rigidity than wood. The rivets must be very carefully fitted and driven to secure the entire absence of play, which is otherwise easily observed. Cross beams between the two A-frames give the necessary lateral stiffness under rolling or listing movements of the ship.

294. How is the framing of the diagonal, direct-acting paddle-wheel engine constructed?

One part of the framing acts to form struts between the cylinders and the bearings of the crank-shafts, serving at the same time as guides for the cross-heads, while another part merely supports the weight of the crank-shaft and its bearings; this part is sometimes replaced by the condenser.

The frames are usually of cast iron or wrought steel standards of I-shaped, square, or round section, with bolted flange connections to the cylinders, main-bearings or foundations.

295. How is the framing of the horizontal, direct-acting Western river stern-wheel engine constructed ?

It consists principally of two wooden, or steel, beams placed directly upon the deck beams of the main deck of the boat Of these only the inside one extends to the stern-wheel for the support of the main-bearing, wheel-shaft and wheel and for taking the thrust of the engine. The shorter beam, on the outside, shares with the inside one the weight of the cylinder and the downward thrust of the cross-head As these beams rest on a somewhat yielding and flexible foundation, the connection of the beam to the cylinder and guides is usually made adjustable, so that a realignment can be readily effected.

CHAPTER FOURTEEN

STATIONARY PARTS OF A MARINE ENGINE, II.

The Bed-Plate, Foundation and Shaft Supports.

296. What are the functions and construction of bed-plates and foundations of a vertical screw engine?

The bed-plate of a vertical screw engine provides a support for the crank-shaft in the main-bearings, and connects the main-bearings rigidly to the framing, so that the center of the shaft is always at the same distance from the central position of the piston. It is fastened by numerous bolts to the framing or inner bottom plating of the ship to ensure an absolutely immovable position of the engine in the ship, even under rolling and pitching movements in a seaway. The bed-plate is usually a system of deep cross-girders that contain the bearings, joined at the outside of longitudinal girders; thus forming between themselves pits in which the cranks revolve.

These girders are usually of box, I or ⊐-shaped sections, stiffened by webs. In certain constructions, as where saving of weight is of importance, a special engine foundation is constructed of wrought-steel plates and angles, which carries a shallow cast iron or cast steel bed-plate at its top. Numerous bolts make firm connection between the two parts. Where this foundation is constructed on an inner bottom it is possible to make the crank pits water and oil tight, and thus prevent the bilges from becoming foul with oil.

297. What are the functions and construction of the bed-plates and foundations of a vertical beam engine?

In the beam engine the A-frames take partly the duty of a bed-plate by providing the seats for the main and beam bearings. Under the engine and condenser the air pump channel-way connects the foundation of the A-frames, and transmits thereby the reaction of the engine to the bottom of the boat.

298. What are the functions and construction of the bed-plate and foundation of the diagonal direct-acting paddle-wheel engine?

The bed-plate of the diagonal engine is usually made in several pieces; the part under the cylinders being frequently in form of feet or brackets that connect to the foundation built into the ship. The other parts are shallow girders, substantially bolted to the framing or foundation of the ship, in order to support the standards, or condensers, under the main-bearings, air-pump channel-ways, feed-pumps, reversing engines, cross-head struts, etc.

Being well distributed over a large area of the framing, a good, secure foundation and a well-aligned engine is thus gained.

299. What are the functions and construction of the foundation of the horizontal stern-wheel engine?

In the horizontal stern-wheel engine the framing takes the place of the bed-plate. Under the wheel beams a form of lattice girder of wood or steel helps to preserve the rigidity of form in the hull and engine, and to distribute the strain of the engine working over a larger area.

300. What are the functions and construction of the main bearings?

The main-bearings serve for the support and alignment of the driving shaft of all marine engines. Their principal func-

tion requires a very careful construction to ensure the successful continuous propulsion of the ship.

In the paddle-wheel types of engine the main-bearings have to transmit the whole thrust of the wheels to the ship, which makes their duty so much the more arduous. Special connections must be provided, and in beam and stern-wheel engines the bearings fit over, or between, projections of the foundation, or framing, with adjustable keys between.

In the diagonal engine the main-bearings have a bracket extending to a cross girder to transmit the thrust to the side-framing of the ship.

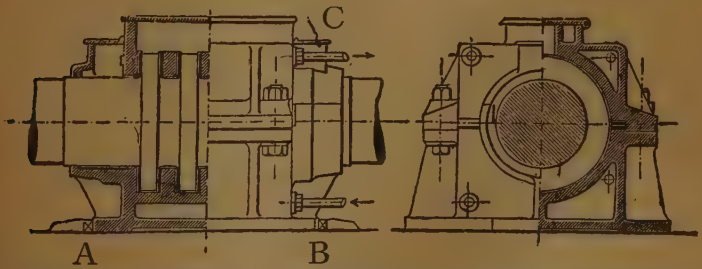


FIG. 96.—Thrust Bearing of a Propeller Shaft. A, B and C, keys and rods to transmit thrust to foundation.

Since the out-board bearings of side-wheel engines need very substantial supports, special constructions, like additional A-frames, or brackets, have to be resorted to for realization of this end.

In screw engines all the thrust-taking is concentrated upon a single special bearing, fitted with horseshoes and ribs in the bearing, for the engagement of corresponding collars on the shafting. The other bearings sustain the transverse strains only. In the bed-plate the crank-shaft bearings sustain severe alternating strains, while in the tunnel the shafting requires only support of its own weight.

Screw shafts leave the ship under water, and have, therefore, a water-tight stuffing-box fitted at this junction. A tube called a stern-tube, is fitted for this purpose with a stuffing-box at its forward end, and providing a special bearing of large surface at each extremity. In twin-screw vessels the shafting outboard of the stern-tube needs additional supports particularly next to the propeller, which is furnished by struts of A-shape. The bosses of these struts provide a large bearing surface to support the weight of the shaft and propeller. The main body of all bearings is usually of cast iron with the top part removable and held and adjusted with bolts.

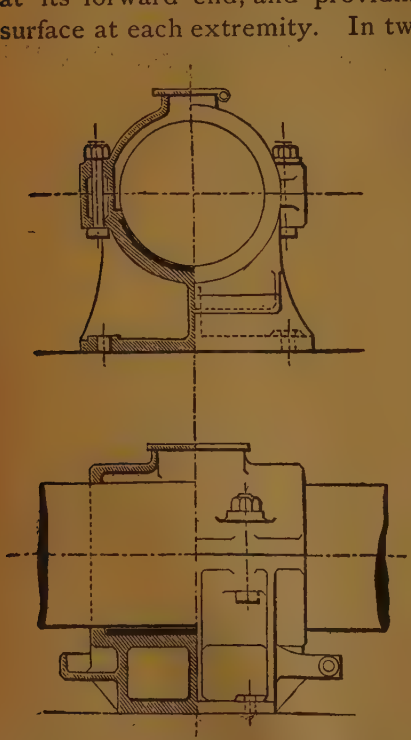


FIG. 97.—Tunnel Bearing of a Screw Propeller Shaft.

To secure a smoother running and less friction bronze brasses are fitted in the upper and lower parts of the bearing. These brasses are formed in square, octagon or round outside shape, and have flanges on each side to prevent all movement sideways. The round and octagon shapes, although less securely held in the bearing, are preferable, as being less easily cracked upon heating and expanding. Distance pieces between the brasses preserve the desired loose fit of the shaft and allow the wear on the brasses to be taken up. Frequently the brasses are lined with strips or blocks, of Babbitt metal, which are easily replaced after

heating or injuring of the bearing surface, besides being a good anti-friction metal.

The joints of the bearings are arranged under an angle from the direction of thrust of the connecting rod. The bolts must be of ample strength for withstanding the whole pull of the piston and should be provided with locked nuts.

Oiling provisions of liberal supply are fitted, and oil-grooves are cut into the brasses, so as to distribute the lubricant over the whole surface.

The screw-engine thrust bearing is fitted in two forms. One form is a regular bearing, with the addition of collar projections, lined with Babbitt metal to secure a uniform bearing of all collars. The other form is an open box, containing a number of horseshoe rings, singly adjustable fore and aft, to secure a well-distributed thrust. The bearings in the stern tube are inaccessible for oil lubrication, and are, for this reason, made very long. With water alone as a lubricant, the bearing material used is lignum vitæ, fitted in dove-tailed recesses of bronze sleeves. The sleeves are well fitted in the tube and connected by bolted flanges with locked nuts. Where the water is very gritty or sandy, Babbitt metal is found a serviceable material for the wearing surface; the action of the sand proving somewhat destructive on the lignum vitæ. In the shaft struts of twin-screw steamers, similar bearings of lignum vitæ or Babbitt, in bronze sleeves, are fitted, allowing of an easy removal and replacing of the bearing material.

CHAPTER FIFTEEN.

THE MOVING PARTS OF A MARINE ENGINE, I.

THE VALVE-GEAR AND REVERSING MECHANISM.

301. What are the moving parts of a steam engine?

(1.) Valve-gear.

(2.) Piston, piston rod, cross-head and connecting-rod.

(3.) Crank and line shafts.

302. What is the function of the valve-gear?

The valve-gear has the important function of directing and regulating the admission and exhaust of the steam, and producing thereby the regular reciprocation of the piston.

It also enables reversing the direction of the revolution of the crank at the will of the engineer. In short, it is the agent that realizes, more or less perfectly, the aim of producing the largest amount of mechanical work from the steam; doing this by harmonizing and compromising the four periods of the action of the steam, and giving to each of them its due consideration.

Sometimes an extra valve-gear is made, in case it is desired to have the periods of admission and expansion of special length, without interfering with or disturbing the economical and desirable performance during the other periods. In the slide and piston valves this special expansion gear is separate from and entirely independent of the main distributing valve gear. It has lost its importance with the multiple cylinder engines, since in them only a small variation in each cylinder is desirable, and this may be readily obtained by linking-up.

In the single cylinder beam engine a special expansion may be quite useful, and is provided by a drop arrangement for disconnecting the valve stem from the lifting rod and letting the valve fall to its seat before the rod has completed its lift.

303. What are the moving parts of the valve-gear?

The moving parts of the valve-gear are:

The valve, valve stem, link and link-block, eccentric rods, straps and eccentrics, besides the reversing gear for slide and piston valve engines; and the poppet valves and stems, lifting-rods, toes, cams, rockshafts, levers, eccentric rods, straps and eccentrics for poppet valve engines.

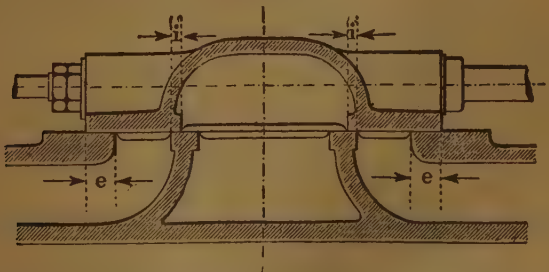


FIG. 98.—Diagram of the Laps of a Slide Valve. The external, or steam, lap is shown at e, the internal, or exhaust, lap at l.

304. What are the parts that direct and regulate the steam distribution?

The steam distribution depends upon the angular advance of the eccentric before the crank, the stroke and the inside and outside laps of the valve, for slide and piston valves; while for poppet valves the angular advance of the eccentric, the length of the rock arms, the stroke and curvature of the toes are the determining factors.

305. What is the angular advance of the eccentric?

The angular advance is the angle *d*, through which the eccentric is turned ahead of a position 90 degrees ahead of the crank.

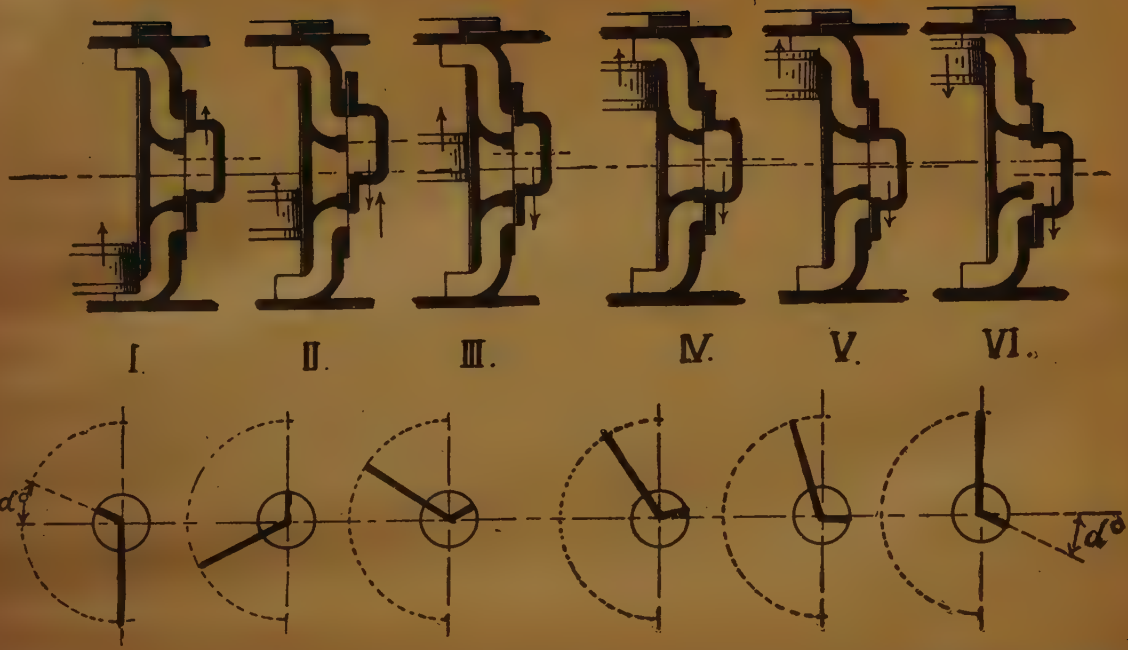


FIG. 99.—Relative Positions of Piston and Slide Valve; also Corresponding Positions of Crank and Eccentric Arms, through one complete stroke of the piston. The angle designated as d° shows the angular advance of the eccentric.

306. What is the influence of the angular advance of the eccentric?

The angular advance of the eccentric provides for a certain opening of the ports, when the piston is in the end position. At one end full steam pressure is thus ready to start the piston on its return stroke, while at the other end the fully established exhaust prevents any undue back-pressure. A larger angular advance of the eccentric increases the lead, shortens the admission, lengthens the expansion and makes the exhaust and the compression earlier, besides lengthening the latter.

307. What is the lead?

Lead is the amount of port opening at the end position of the piston, which gives the steam an opportunity to enter behind the piston and start it again with full, strong pressure. It is provided by the angular advance, and is usually expressed in linear measure of inches. The amount given varies in different engines from nothing to three-eighths or one-half inch for modern marine practice.

308. What are the outside and inside laps?

The outside and inside laps are the excess of the width of the valve face over the width of the port in the direction of the travel of the valve; they are marked *e* for the outside or steam lap and *i* for the inside or exhaust lap in Fig. 98.

309. How do the inside and outside laps influence the steam distribution?

The outside lap determines the angular advance to secure a certain lead. It makes the cut-off earlier and lengthens the periods of compression. The positive inside lap decreases the exhaust lead or premature opening of the exhaust port. It lengthens the period of expansion; decreases the period of exhaust, and lengthens the period of compression.

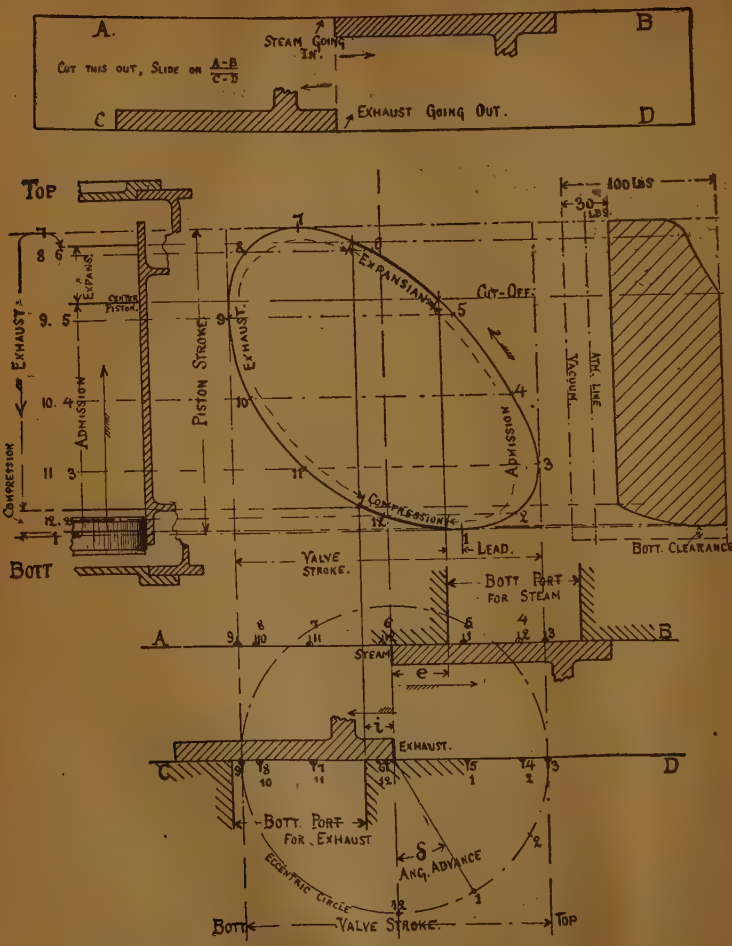


FIG. 100.—Valve Diagram for a Vertical Slide or Piston, Valve Engine. This diagram shows the relative positions of the piston and valve. The piston moves vertically, while the valve moves horizontally. Equal numbers indicate corresponding positions for both. The cut-out slide shows progressively, from one number to the next, how the valve opens and closes from 1 around to 6 at the upper steam edge, and from 6 around to 12 at the lower exhaust edge. The piece at the top of the diagram represents the slide valve, and, if cut out and laid upon the corresponding letters on the centre figure, gives graphic illustration of the movement of the valve.

If the inside lap is negative its influence on the different periods is reversed.

310. What is the relation between the stroke of the valve and the outside and inside laps?

The laps should be proportioned as a certain part of the valve stroke.

The outside lap, which is always positive, may vary from nothing to not more than one-fourth of the stroke. The inside lap may vary from a small negative value to a positive one of about one-tenth or one-twelfth of the valve stroke.

311. What is the amount of angular advance most often found in marine engines?

The angular advance varies from nothing to about 40 degrees. Thus, with no angular advance, there is usually associated no outside lap, while a large angular advance is usually associated with a large outside lap.

312. How do we obtain a graphical demonstration of the influence of angular advance, lead and laps?

The valve diagram is used to show the influence of the different factors that affect the steam distribution.

The ellipse diagram, as shown in Fig. 100, shows the position of the piston of a slide valve engine for each twelfth of one revolution and the corresponding position of the valve.

The edge, AB, shows the travel of the steam lap, *e*, from its centre position across the port and back; the edge, CD, shows the travel of the exhaust lap, *i*, across the port and back, also from its centre position.

The port is, in both cases, the bottom one, so placed that the steam, as well as the exhaust lap edges, fall on the middle line of the valve stroke.

The four periods of the steam distribution are begun when the lap edges pass the port edges. The diagram at the

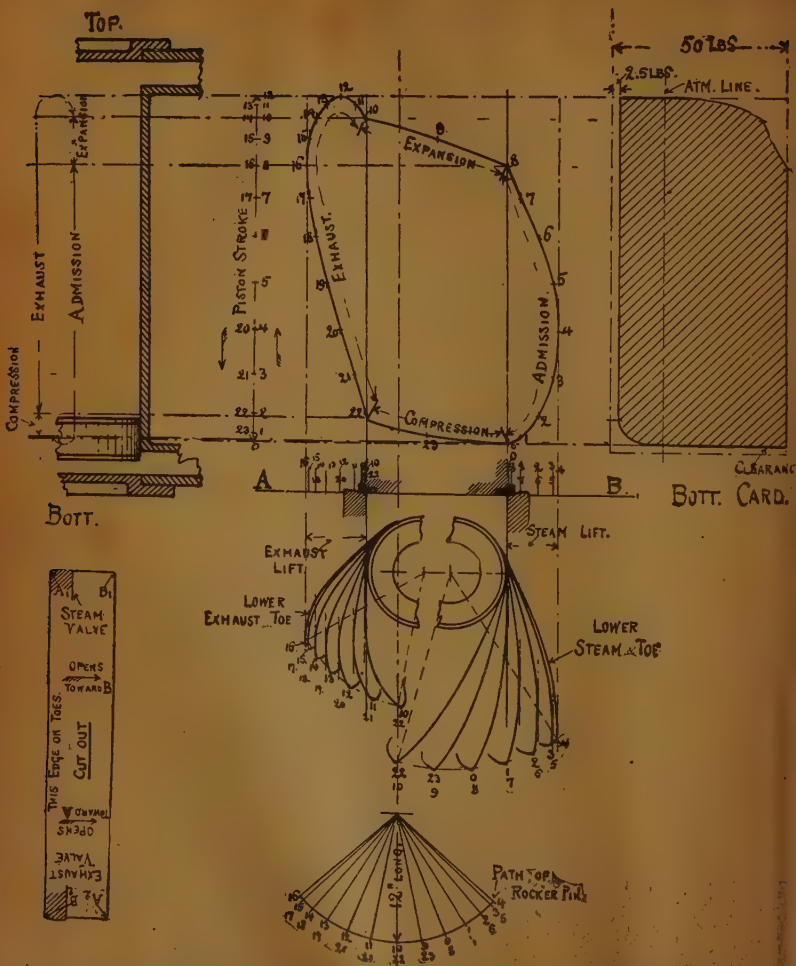


FIG. 101.—Valve Diagram for a Beam Engine with Poppet Valves. This diagram shows the relative positions of the piston and poppet valve. The piston travels vertically while the toes swing horizontally, lifting the valves in the same direction. The valve rests, in the diagram, directly on the toes. The cut-out slide valve, at the left of the diagram, is to be placed in vertical position and moved horizontally resting successively upon the toe in the positions from 1 around to 7, for the steam and on the other edge and other toe, from 10 around to 22, for the exhaust.

right shows the indicated power that would result from this setting of the valve, with 100 pounds initial absolute steam pressure and 30 pounds exhaust pressure.

A diagram for the poppet valve-gear of a beam engine is shown in Fig. 101 for every twenty-fourth of one revolution.

The ellipse does not show so evenly, as the valves come to a pronounced stop at the end of each period.

The steam distribution, in this case, depends upon the angular advance of the eccentrics, which can be different for steam and exhaust, due to separate eccentrics and rock shafts, and upon that part of the swing of the toes that actually lifts.

Through this combination a result similar to that of laps in the slide valve is obtained, defining very clearly the four periods of the steam distribution.

313. What is the influence of linking-up on the steam distribution?

Linking-up puts the valve under the combined influence of the ahead and backing eccentrics, which has the same effect as if the valve was actuated by a single eccentric of shorter stroke and greater angular advance. The lead increases with open eccentric rods, while it decreases with crossed rods. Linking-up is only desirable in small amounts, as not only the expansion, but also the compression, begins earlier, and reduces the power developed very quickly.

With a special expansion gear the expansion only is affected, and the reduction of power is more proportionate to the reduction of steam consumption, while the compression remains constant.

314. What forms of valve are in common use?

(1) Valves sliding across a steam port constructed as flat slides or pistons.

(2) Valves lifting away from the ports, constructed as poppets, usually in the double balanced arrangement.

315. What is the duty and construction of the sliding valves?

The sliding valves work on a flat or cylindrical face, with a steam-tight fit, which prevents an exchange of the high and low pressure steam, outside and inside of the valve. For this reason the valves are usually of cast iron, the same material of which valve chests are made, securing thereby practically the same expansion.

Flat side valves are constructed with single or double

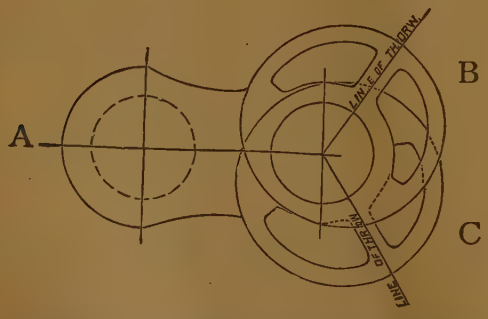


FIG. 102.—Diagram Illustrating the Relative Positions of Crank and Double Eccentrics when the Crank Stands at Instroke Dead Centre. A shows the crank; B, the forward eccentric, and C, the backward eccentric. The angular advance is indicated on the lines of throw of each eccentric.

ports, while piston valves are mostly applied to single ports only.

To keep steam tight fit under conditions of wear the flat valves have a supporting spring on the back, besides having the steam pressure on the back of the valve.

For large, flat valves this excess of pressure may be so severe that relief rings have to be fitted, excluding part of the back from the access of the steam and connecting it with the condenser.

Piston valves for small sizes are constructed as neatly fitted plug valves, with water grooves turned in their faces and no

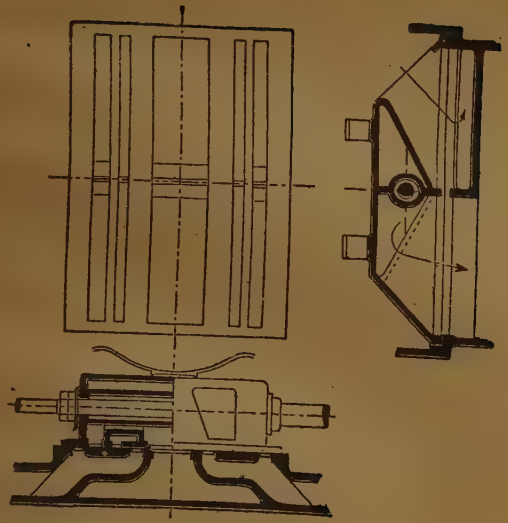


FIG. 103.—Double-ported Slide Valve.

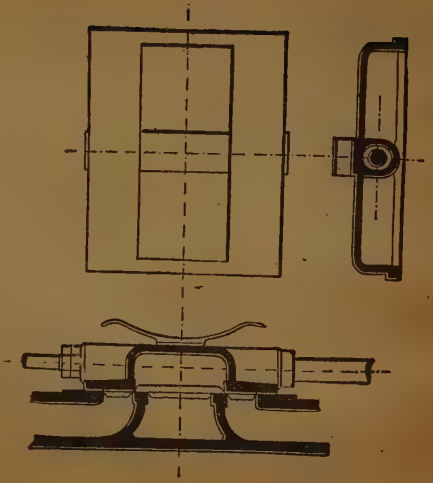


FIG. 104.—Single-ported Slide Valve.

provision for wear. Larger piston valves have frequently a split, but bolted, packing ring, that can be spread in case of wear.

Flat valves are frequently preferred for low pressure cylinders as being more secure against leakage of steam to the condenser.

316. What are the functions and construction of the lifting valves?

The lifting valves are usually in the beam engine arranged in the double balanced form, so that the valve gear has little more strain imposed upon it than lifting the weight and overcoming the friction.

There are usually four pairs of these valves, closing on narrow, conical seats of bronze and fastened in the valve chest.

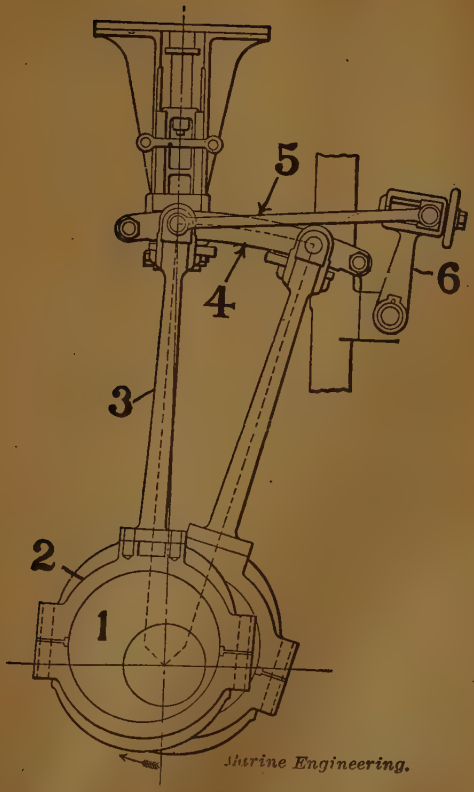
The valves and their distance piece are of cast iron or bronze.

317. What are the functions and construction of the valve stems?

The valve stems transmit motion to the valve, and help to guide it in its path.

As they are subject to pulling and pushing strains, they should be heavy enough to remain rigidly in a straight line, even under the heaviest pressure that can come on them. In flat slide valves they fit loosely through the valve body with large washers above and below it.

In piston valves a tight fit, with collar below and nut above, is usually provided. For large valves an upper guide sleeve is provided for steadying the movement and preventing overhung bending of the stem. The lower end of the stem passes through a steam-tight stuffing box, which guides it. Large stems have also an outside guide for relieving the stuffing box of all outside pressure.



Marine Engineering.

105.—Type of Stephenson Link Motion, Double-Eccentric Reversing Gear. The figured parts, as referred to in the text, are: Eccentric (1); eccentric strap (2); eccentric rod (3); shifting link (4); suspension rod (5); reverse arm with adjustable pin (6), mounted on the rock shaft.

With link reversing gear, the valve stem has a fork or bearing at the end that connects to the link block, or, to the swinging lever of radial valve-gears. With lifting valves the stem is in one or two parts; in the horizontal river engine the valve stem, passing through a stuffing box, connects to a lever; in the beam engine this stem connects to a bracket arm that reaches out from the lifting-rod in the front.

With a drop expansion gear this bracket arm of the steam lifting rod has a slotted bore, which drops or carries the valve stem, according to the engagement of a toothed rotating collar on the stem. A dash pot secures a retarded movement and easy closing of the valve on its seat.

318. What is the function of the reversing-gear?

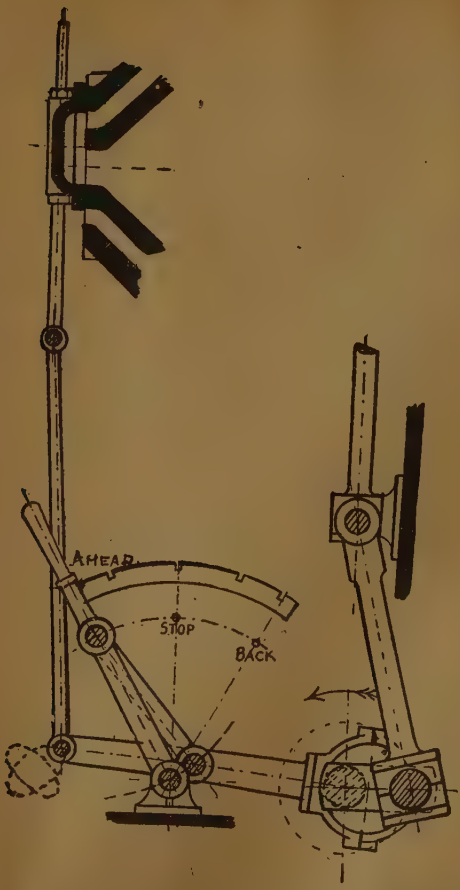
The reversing gear provides for the change of direction of the revolutions of the propeller. For vertical engines the link gear and the radial, swinging lever gear are most frequently used.

The link gear, best known in the Stephenson form, employs a sliding link connected to two separate eccentrics one for ahead, the other for backing motion, each with the normal angle of advance.

The radial valve gear, best known in the Marshall form employs one eccentric set, at 0, or 180 degrees from the crank pin, or it derives its motion from the connecting rod. The swinging lever so actuated is guided at its other end in a certain curved path, enforced by slides or guiding levers, that drive the valve stem pin in an elliptical path, similar to the valve diagram ellipse. On reversal the ellipse is turned the other way.

In beam engines backing is frequently done by actuating the lifting rods entirely by hand and suspending the automatic action.

Sometimes an independent backing eccentric and rod i



. 106.—The Marshall Valve-gear. The single eccentric, turning with the crank, works the valve through a pivoted arm. The movement of the engine may be stopped or reversed by sliding the hand lever on the notched quadrant. The loop paths show the movement of the valve rod pin and also of the valve in vertical directions for ahead or backing motion.

fitted that engages the rocker arm when the ahead eccentri
rod is lifted off.

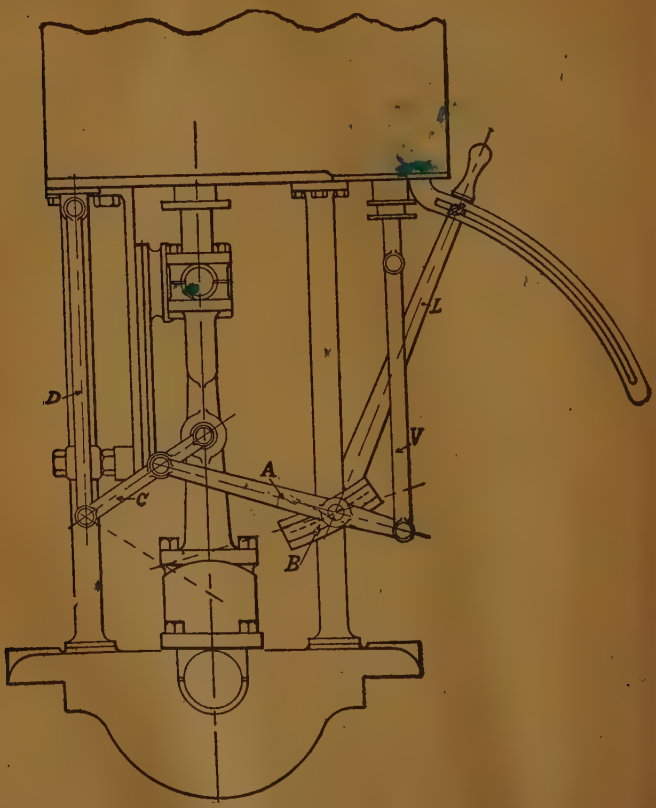


FIG. 107.—Radial Valve-gear for a Marine Engine. The lever, A, operates the valve rod
The pin forming the fulcrum of A slides in the curved slot, B, motion being dire
imparted to A from the connecting link, C, one end of which is pivoted to the
necting rod, the other to the suspension link, D. The vertical motion of the link
moves the valve, as desired. L is the reversing lever.

319. How is reversing with link gear accomplished?

Reversing with link gear is effected by pushing the li
over until the backing eccentric rod pin is directly under

block pin. Suspension rods are for this purpose connected to pins at the centre or end of the link, which at their other ends are hung up to a rocker arm on the reverse shaft. For multiple cylinder engines each link has this independent connection to the reverse shaft, which in turn is rotated through the necessary angle by either hand or steam.

The hand gear used is the direct hand lever, or a lever pushed over by a screw shaft with hand-wheel, that increases the leverage to the necessary degree.

Steam reversing is done in one type by a continuously rotating small engine that actuates the rocker arm of the reverse shaft through screw, worm-wheel and connecting rod.

The other type of steam reversing employs a reciprocating steam cylinder, sometimes in conjunction with an oil cylinder, that checks and prevents any small vibratory motion of the gear.

The piston, piston-rod and cross-head connect directly with connecting rods to the rocker arm, and a floating lever is employed for preventing an excess of the normal stroke by automatically closing the valves for steam and oil cylinders.

320. How is reversing accomplished with radial gears?

Reversing in radial gears is effected by changing the guide path of the swinging lever through connection to a hand lever or steam reversing gear.

321. How is reversing effected with poppet valve-gears?

If a special backing eccentric and rod is fitted, then the reversal is accomplished by lifting the ahead eccentric rod up out of reach of the rock arm pin, while the other one is lowered until it engages the backing pin on the rock arm.

322. What forms of links are in use on marine engines?

The slotted and the double bar link are the forms best known in marine practice. The slotted link has the eccentric

pins below the circle of the link block pin and the suspension rod pin in the end of the link. The double bar link has the eccentric rod pins on the circle of the link block pin, either in the ends of the links or coinciding with the block pin in the extreme positions. The suspension rod pin may be, in this case, in the middle or end of the link. The double bar type is considered preferable for large engines of modern design, as being more accurate and less subject to wear.

323. What is the slip of the link?

A peculiarity of link gears is a slight oscillating movement of the link on its block, called the slip.

This should be kept as small as possible to prevent, or reduce, undue wear of the block. The position of the suspension rod pin is of great importance in guiding the link up and down in as straight a line as possible.

324. What is the construction of the link, link block and pins?

The link is generally constructed of wrought steel bars, curved to the radius of their distance from the centre of the crank-shaft.

The double bars are bolted together at the ends by collared bolts, and the pins are either forged on or are secured by tapping into the bar. The finished edges should be broad enough to give good bearing surface for the block brasses.

The link block of wrought or cast steel has a pin for the bearing of the valve stem between two cheeks, which carry overhung lips for resting on the link bars.

These lips are provided with adjustable wearing brasses that maintain a nice sliding fit of the block on the link.

325. How are the other parts of the reversing gear constructed?

The parts that transmit the reversing motion from the

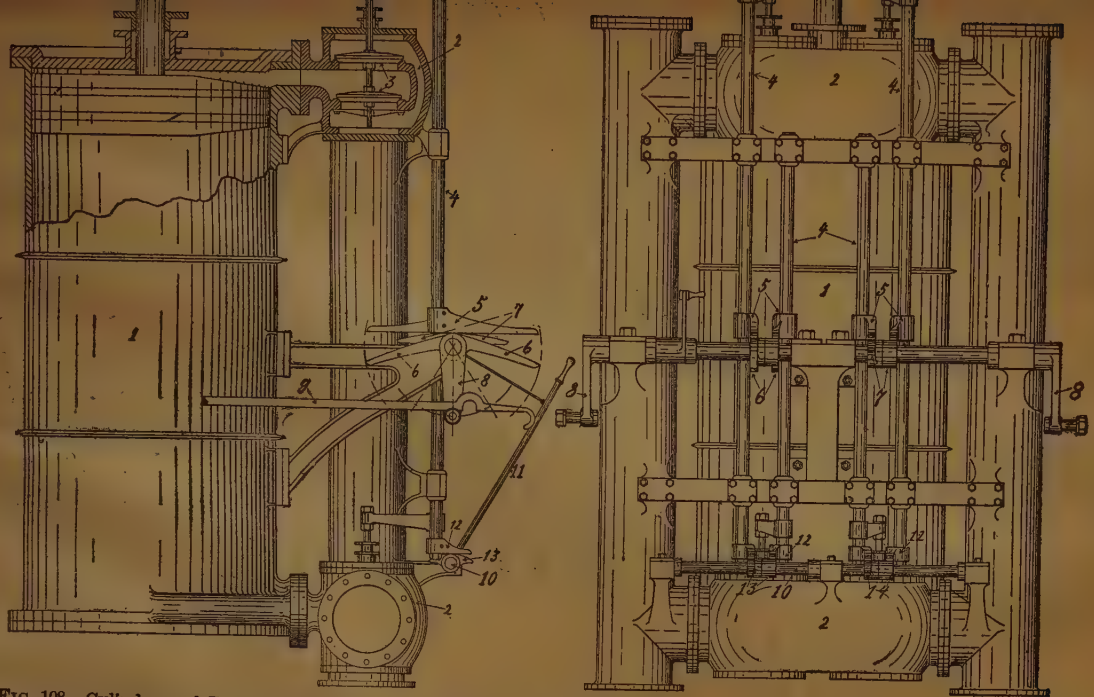


FIG. 108.—Cylinder and Poppet Valve Gear of a Beam Engine. The numbered parts are: The cylinder (1); the valve chest (2); the double-seated poppet valves (3); the lifting rods (4); the lifting toes (5); wipers for the steam valve (6); wipers for the exhaust valve (7); the rock shaft arm (8); the eccentric rod (9); small rock shaft (10); lever to operate valve-gear by hand (11); lifting toes (12); steam valve wipers (13); exhaust valve wipers (14).

hand lever or steam cylinder to the link should be stiff and rigid, to prevent any uncertainty in the action of the link.

The suspension rods are of forged or cast steel in round or flat bar or I-section, with adjustable brasses on each end.

The rock arms are made of forged or cast steel in flat or I-shapes. They are securely keyed to a rigid shaft with heavy bosses, while on the other end smaller bosses receive the pins for the suspension rods.

These pins frequently slide in a slot, actuated by a screw which allows a certain linking-up independently for each cylinder. The reverse shaft should be well supported in bearings, particularly near all the rocker arms, to prevent bending and deflection as effectively as possible.

326. How is the lifting gear of the beam engine actuated and constructed?

The toes of the lifting rods of the beam engine are actuated by curved cams keyed to a transverse shaft. Four cams are fitted, two for steam and two for exhaust.

The oscillating movement is obtained from rocker arms one on each end of the transverse shaft, the pins of which are engaged by hooks in the eccentric rods.

Toes, cams and rocker arms are frequently of cast iron while the shaft and pins are of wrought iron or steel.

The curvature of the cams is such that the lift of toe rods and valves is very small at the beginning, but rapidly rises to the maximum with the reverse action on the down movement.

327. How is the lifting gear of the Western river poppet valve engine actuated and constructed?

The levers of this type of engine are actuated by cams very similar to those used on the beam engine.

The cams and rock arms are made frequently of cast iron, while the levers and the shaft are of wrought iron or steel.

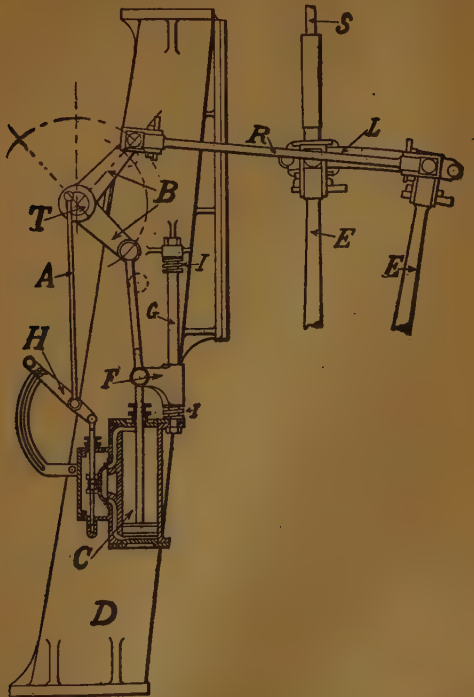


FIG. 109.—Steam Reversing Gear, Used with a Marine Engine Equipped with the Stephenson Link Motion. To the column, D, is attached the steam cylinder, C, which actuates the bell crank, B. One arm of this bell crank carries the reach rod, or link, R, which is connected, as shown, to the shifting link, L. The valve of the cylinder, C, is controlled by the hand lever, H; and when this is turned so as to admit steam to the bottom face of the piston, the bell crank, B, and link, R, describe the paths indicated by the dotted arcs, thus shifting link, L, to the left, and reversing the action of the eccentric rods, EE, on the valve stem, S, of the main cylinder. Other lettered parts are: T, the tumbling shaft on which B is pivoted: G, guide rod on which the crosshead, F, slides; I and I, cushion springs against which F strikes, thus preventing the piston of C from striking the cylinder heads.

328. What purpose do the eccentrics and eccentric rods serve, and how are they constructed?

The eccentrics and their rods transmit the revolving motion of the shaft to the reciprocations of the valves.

An eccentric is only a short crank with a pin of very large diameter.

The eccentric revolves in the strap, which is analogous to the crank pin brass of the connecting rod, divided and clamped by bolts, with distance pieces between the valves for easy fitting and taking up of slack after wear. The rods are an extension of the straps for connection to links, valve-stems or rocker-arms.

The eccentric must be substantially held on the shaft by keys or set screws, and must be strong enough to transmit the bending movement of the eccentricity.

The strap has to be proportioned for bending, while the rod for efficient transmission of thrust demands a section and sizes that rigidly preserve its form.

The eccentrics are usually cast iron or cast steel sheaves of sufficient width to offer a good bearing surface. The straps are frequently of cast iron, lined with Babbitt metal, or of bronze in T-section. Little lips are often found on the sides of the strap that are intended to retain the lubricating oil longer between eccentric and strap. For small engines the straps and rods are found in one piece, while larger engines show the rods independent, bolted or tapped to the strap.

The rods are made of wrought or cast steel in round, flat or I-sections. For link gears their upper ends receive bearing brasses that engage the pins or bolts in the links.

The bearings should be split and bolted and amply large, as lubricating these pins is often not very convenient, and therefore easily neglected.

In beam engines the eccentric rods are of great length and a rod built up of flat, wrought-iron bars in shape of a tapering lattice girder is found best adapted for attaining the end of rigidity. The extreme end is a solid bar, with a notch for hooking on to the rock arm pin.

CHAPTER SIXTEEN.

THE MOVING PARTS OF A MARINE ENGINE, II.

THE PISTON, PISTON ROD, CROSS-HEAD AND CRANK AND LINE SHAFTS.

329. What is the function of the moving parts that receive their motion from the cylinder pressure?

The cylinder moving parts transmit the pressure of the steam in the cylinder to the shafting. They are the piston, piston rod, cross-head and connecting rod, and are all subject to the severest strains of tension, compression or bending.

Their bearing surfaces should be liberally proportioned and arranged for ample and uninterrupted lubrication.

330. What is the function of the piston, and how is it constructed?

The piston has to collect the uniform steam pressure in the area of the cylinder, and transmit it in concentrated form to the piston rod. It is loose all around its rim, but must still be steam tight, in order to retain the excess of the live steam pressure on one side.

For giving the piston this quality of tightness, expansive piston rings are employed, which are lightly pressed against the wall of the cylinder by springs or by their own elasticity. The rings can slide radially between fixed, or removable, flat collars, or follower rings, that carry them along with the piston during its travel. Behind the gap of expansion in the ring a pad of the same width as the ring is fitted to prevent the steam from getting in behind the ring.

The tap bolts of bronze, that hold the follower ring, hav special square nuts of steel or brass fitted between lugs in th body of the piston.

The piston is either a hollow body of cast iron, closed b discs, with stiffening webs between them or a solid conica body of forged or cast steel. The piston rod is fitted int the bore of the boss, usually with a steep cone to get thor ough steam-tightness, and still make removal comparativel easy.

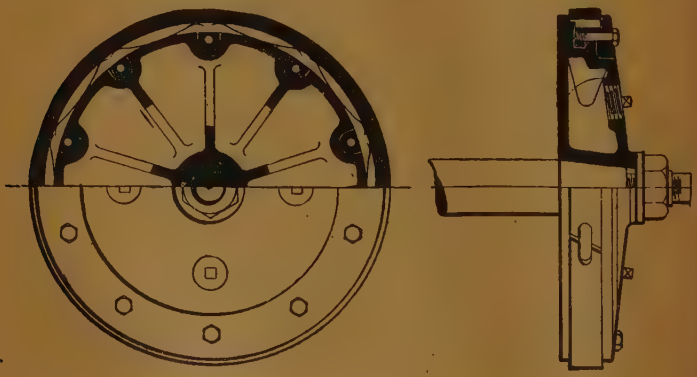


FIG. 110. – Half-sectional Diagrams showing the construction of the Piston.

331. What are the office and construction of the piston ro and the cross-head?

The piston rod transmits the thrust from the piston insid of the cylinder to the connecting rod outside of it.

It passes, for this purpose, steam-tight through the stuffin box in perfectly cylindrical shape, and its surface should b perfectly smooth, to prevent tearing of the packing materia Steel is usually employed for it, with coned seat for fitting th piston and a locked nut for preventing the piston from worl ing loose. The outer end of the rod is sometimes extende

into a guide sleeve or through a stuffing-box for better support and more uniform wear of the piston and its ring.

Stiffness is greatly to be desired in piston rods, as the wear in the stuffing-box and in the cylinder depends a good deal upon it. The end of the rod near the crank or walking beam is connected to the cross-head either by bolting, keying or strapping, or by forging them both in one piece.

The cross-head of forged or cast steel guides the end of the piston rod in a perfectly straight line, and neutralizes the transverse reaction pressure of the connecting rods in the slipper guide. It is of square or round section, with flat slippers or jaws

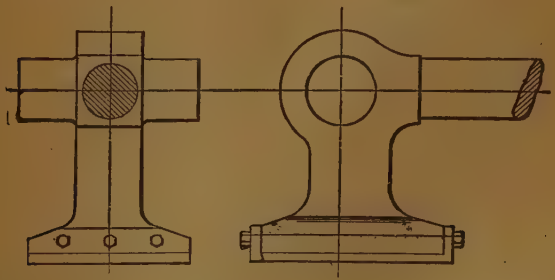


FIG. 111.—Cross-head Forged in One Piece with the Piston Rod.

on one or both ends that rest upon the guides. The slippers or jaws are usually independent, and bolted adjustably to the cross-head. The bearing faces are fitted with Babbitt metal strips for better wear and easy renewal. The channels between the strips serve as oil grooves. Large surface is desirable on these slippers, particularly with short connecting rods, where the thrust is quite heavy.

The cross-head either supports the pins for the upper connecting rod bearing, or it forms the bearing in a slot, to which brasses, a cap and holding-down bolts are fitted, as to any other adjustable bearing.

332. What are the function and construction of the connecting rod?

The connecting rod transmits the straight movement and thrust to the revolving crank, overcoming its tangential resistance. Severe bending, pulling and thrusting strains have to be overcome, and it is, therefore, usually of solid or hollow, round or I-section, as best able to resist these strains.

With the long connecting rods of beam and stern wheel engines, the usual section, constructed in steel, proves either too heavy or too elastic for efficient thrust transmission. In

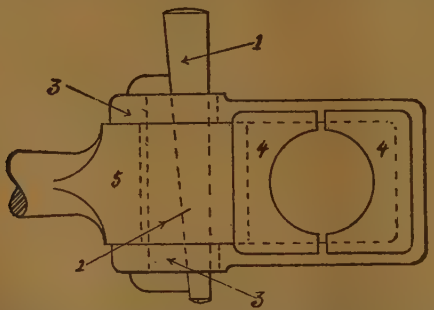


FIG. 112.—The Crank End of a Marine Engine Connecting Rod. The numbered parts are the crank pin key (1); the crank pin gib (2); the crank strap (3); the crank brasses (4) the connecting rod and crank pin (5).

beam engines a truss is, therefore, added to the rod in the direction of its swing, adding greatly to the rigidity.

The beam engine has, directly attached to the cross-head two short connecting rods of usual construction that engage the pins of the walking beam. This walking beam, the special feature of the beam engine, rests with heavy pins bearings on the top of the framing; and consists of a cast-iron centre, surrounded by a wrought-iron strap, carrying pins either end for the connecting rod bearings.

In stern wheel engines a wooden rod is employed of very large, round or octagon, section, gaining great stiffness with

light weight. An iron strapping is employed for transmission of tension stresses and connection to the iron stub ends that carry the bearings.

The upper end of the connecting rod is jointed with a bearing to the cross-head by carrying either the pin or the bearing brasses. Generally the connecting rod end is forked. Great care must be exercised in fitting the pin, or the brasses, exactly parallel to the crank pin.

Some engineers object to forked-end brasses, as being liable to heat from difficulty of alignment.

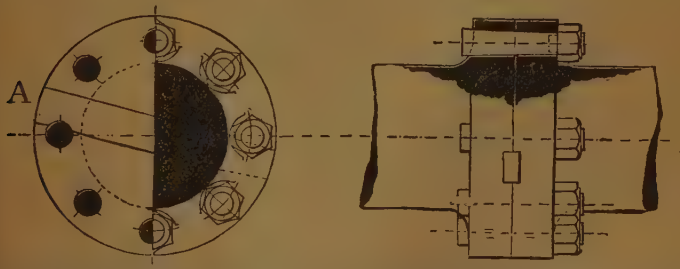


FIG. 113.—Shaft Couplings, showing method of uniting two sections of the line shaft by flanges and conical bolts. At A in the left-hand figure is shown the key running diagonally through the coupling, to insure further security to the joint.

The lower end bears the crank pin brass, one of the most important bearings in the whole engine. It is split and fitted with distance pieces, and the cap is held down to a broad foot of the rod with two strong bolts.

Another bearing connection, to stub ends of connecting, as well as eccentric, rods, is made by gibs and keys, that find great favor with many engineers (see Fig. 112.)

The nuts of all the important bolts in the moving parts are locked by set screw rings or lock plates, which obviate all possibility of the parts working loose. The brasses have a little side play on the crank pin between the webs to prevent binding and heating on small lateral movements of the crank shaft.

333. What are the functions and construction of the cran shaft and the line shafting?

The crank shaft transforms the reciprocating motion of th connecting rod into a revolving motion, which is then tran mitted by the line shafting to the propeller. The crank sha is exposed to severe bending and twisting strains, and nee liberal support by bearings as well as ample strength.

It is usually of steel, in either forged or built up constru

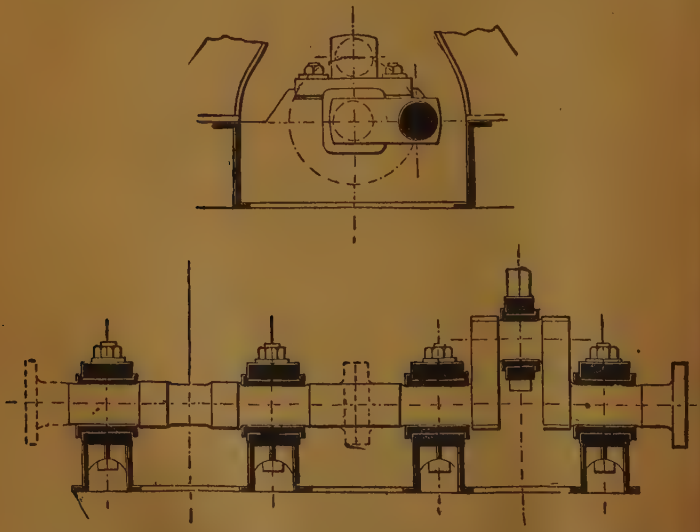


FIG. 114.—Details of a Crank Shaft, showing bearings and coupling disk.

tion. The forged construction is lighter, while the built- construction is more easily repaired.

Large shafts for multiple cylinder engines are always several sections, interchangeable, so as to need only one spa section. In built-up cranks the webs should be well key and shrunk to the shaft, while the pins are usually o shrunk in.

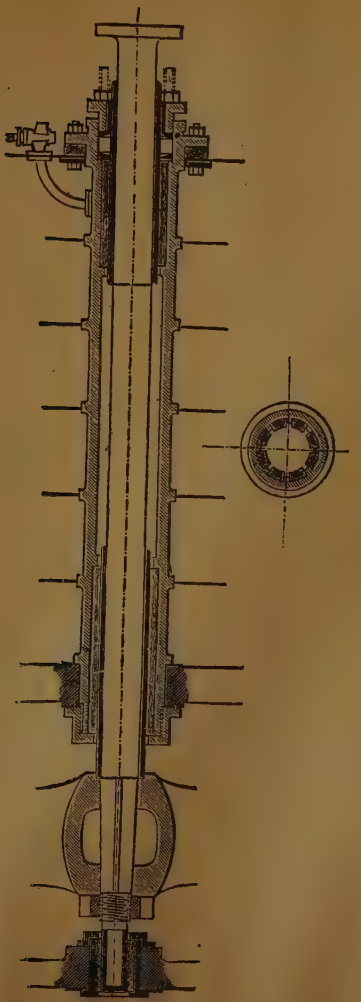


FIG. 115.—Screw Propeller Shaft and Stern Tube Fittings.

In modern engines, shafts, as well as pins, are frequentl bored or forged hollow, saving weight and gaining in relia bility of construction.

The crank webs have a little play sideways between th bearings, so that all end thrust is taken up in the thrust bea ing.

Stern-wheel shafts have usually overhung cranks, while a other types have a web and a bearing on each side of th crank pin.

The line shafting of paddle wheels is frequently only direct continuation of the crank shaft, while in stern-whe steamers the crank shaft and wheel shaft are the same. I screw steamers the length of the shafting demands sub-div sion into several pieces, of which the principal ones are: th thrust shaft, usually next to the crank shaft; one or mo intermediate shafts, and the propeller shaft, passing throug the stern-tube.

The connection between these several shafts must be a complished very carefully, as not only torsional strains ha to be transmitted by them, but also pulling and thrustin strains. The most reliable construction is the forging coupling discs on the ends of the shaft, bolted together b conical or cylindrical bolts. Sometimes keys are fitted a ditionally between the flanges, embedded half in one an half in the other, to relieve the bolts of all shearing strains.

The lengths of the different shafts depend largely upon th convenience of getting the shafts into or out of the tunne and through the hatches of the engine room.

Provision must be made to draw the propeller shaft i board, or to otherwise fit a removable coupling that allo the shaft to pass through the stern tube. This arrangement frequently chosen for twin-screw steamers, where the ou board length of shafting may be considerable.

The propeller shaft ends in a taper, with a large lock

Marine Engineering

FIG. 116.—Tail Shaft and Stern Tube of a Screw Propeller, showing details; also method of preventing corrosion by use of a mixture of tallow, white lead and oil, having the consistency of soft soap. This mixture is boiled together and poured, while hot, through the pipe, C, which passes through the peak tank top at B, and opens on the cabin floor through the small flanged deck cap, A. The tube, C, is screwed into the stern tube at D. E is a conical brass flange screwed on to keep parts free from water, being bored conical, so as to compress the marine lapping, F.

nut or key behind the propeller to prevent its working loose.

The propeller shaft is covered in the bearings with brass sleeves, which sometimes extend over the whole surface touched by salt water.

The shrinking, pinning and joining of the different parts must be executed with great care, and engineers have to exercise extreme vigilance on inspection for any indication of corrosion under the sleeves. Where sleeves are used only in the bearings, twine or rubber covering or a thick coat of paint or tallow is employed for protection of the intermediate parts of the shaft.

CHAPTER SEVENTEEN.

OPERATIVE DETAILS OF A MARINE ENGINE.

334. What are the operative attachments used on marine engines?

(1.) Stop and throttle valves.
(2.) Pass-over valves.
(3.) Relief valves.
(4.) Steam jacket valves.
(5.) Drain valves or cocks.
(6.) Hand levers, arcs, shafts, connecting rods and brackets.
(7.) Indicator gear.

335. What are the functions of the stop and throttle valves?

The stop valve is for complete closing-off of the steam from the engine, while the throttle valve is for the regulation of the steam supply for sudden and irregular changes.

The characteristic of the regular stop-valve is tightness, while that of the normal throttle, or butterfly, valve is rapidity of action. Frequently a combination is made into one valve of the double poppet or swinging slide type that is sufficiently tight to prevent leakage of steam into the engine, while easily handled for rapid adjustment to changes.

The stop-valve is arranged in the same manner as the regular boiler stop-valve, in angle form, with flanged casing, cover, valve-seat, valve stem, yoke, stuffing-box and hand-wheel.

The throttle-valve in its simplest form is a straight tube with a swinging disc held by set screws on a stem across the tube. Frequently this butterfly valve is arranged in the stop-valve casing to save space and weight of flanges and bolts.

The combination double poppet valve has the casing so a ranged as to permit the steam to flow freely to both valve In its arrangement of the cover, the valve seats, the valv and distance pieces, it is very similar to the poppet valves the beam engine. The stem leads outside of the casi through a substantial stuffing-box to the hand lever conne tion.

Another form of combination stop and throttle valve is t swinging valve, either with a cylindrical slide or with a cor cal plug. The casing resembles that of an angle valve wi cover, flanged inlet and outlet, stem and stuffing-box. T

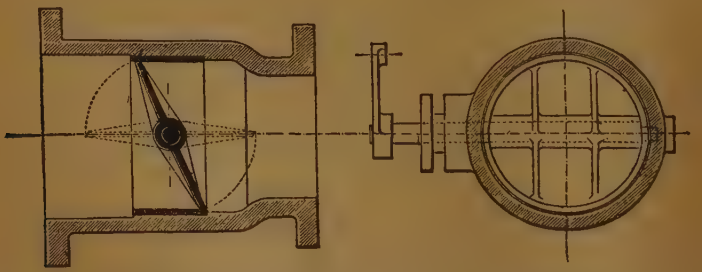


FIG. 117.—Longitudinal and Transverse Sections of a Butterfly Throttle-valve.

stem rotates around its axis, swinging the valve across one more rectangular ports.

With two or more ports it can fulfil the office of intermed ate, or low-pressure, cylinder starting valves. For this purpo small holes through the slide connect, at the half-open pos tion, with the respective auxiliary ports, which, however, a closed in the full open position.

336. What is the function of the pass-over or starti valves?

The pass-over, or starting, valves serve the purpose of e suring prompt starting of the engine, whenever steam turned on. Particularly in multiple cylinders they are need

as with the high-pressure crank on the dead centre, a certain steam supply is required for the intermediate, or low-pressure, cylinders, where an effective crank angle is offered.

Sometimes all cylinder valve chests have a starting valve, while usually one is considered sufficient for promptness of handling. If independent from the main throttle-valve they are flat, slide, or common globe valves. For single cylinder

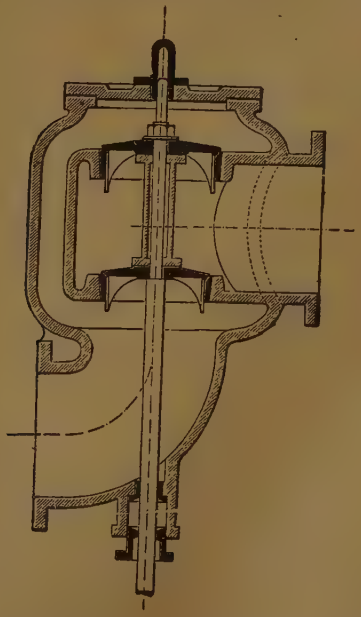


FIG. 118.—Section Through a Double-seated Throttle-valve.

ngines they are sometimes fitted in each end. With the beam ngine steam can be given at any desired time by the hand ear that operates the main valves.

37. What are the duty and construction of the relief valves?

The relief valves are safety valves, and are fitted to prevent ie steam pressure from exceeding a certain fixed point, at

which they blow off. They are fitted usually to the top ar bottom of the cylinders, and one to each valve chest or r ceiver space. The springs are arranged to be adjusted to d sired changes in the pressure. The relief valves are fr quently arranged in a casing to prevent the hot water steam from scalding the attendants.

338. What are the duty and construction of the jack valves?

Where steam-jackets are employed for preventing conde sation, or for warming the cylinders, special valves are a ranged for admission of steam, as well as for the draining-o of the condensed water. The latter are sometimes set so th they just keep the water out of the jacket, but pass no mea ureable amount of steam. They are usually common ang valves screwed, or bolted, to bosses, or facings, on the cyli der casing.

339. What are the use and construction of the drain valv or cocks?

The drain valves or cocks fill the important duty of remo ing the water that condenses in the cylinder, valve-chests receivers. They should be fitted to the lowest point of a spaces or pockets where water could collect. They are som times arranged as automatic steam-traps, which open wh water lodges in them, and close as soon as steam begins to pas

They are regular angle valves or packed cocks with pi connections, that preferably lead to the condenser instead to the bilge, and which thereby save all the fresh water a guard the vacuum against air entering through the low pres ure cylinder.

340. How are these auxiliary valves operated?

All the auxiliary valves are, as far as practicable, operat from the working platform which serves as a stand for the e

gineer, whence he can overlook practically the whole engine; see the different gauges connected to the boiler, the receivers and the condenser, also the clock and the revolution counter.

A stand is provided on the platform, with hand levers, swinging along arcs to which they can be clamped in any desired position. These hand levers are jointed by connecting rods, sometimes through transmission by shafting, to rocker arms on the stems of throttle valve, passing valve, drain cocks, engine reversing valve and injection valve. Without leaving his place, the engineer is thus in full control of the engine.

341. What is the use and construction of the indicator gear?

The indicator gear is for producing the indicator cards that give the steam pressure at any position of the piston, as well as showing more or less clearly the beginning of any one of the four periods in the steam distribution. The gear consists of the valve and pipe connection, from the cylinder to the indicator itself, and of the lever transmitting the motion of the piston, through the cord to the barrel that holds the card.

The pipes lead at either end, through an angle valve, into the clearance spaces, and are joined at the centre by a three-way cock, connecting through an angle to the indicator, in such a position that an easy and direct lead of the cord may be arranged.

The lever is usually driven from the cross-head through a long arm and connecting rod. The short arm or small sheave reduces the swing sufficiently to permit direct driving of the barrel by the cord.

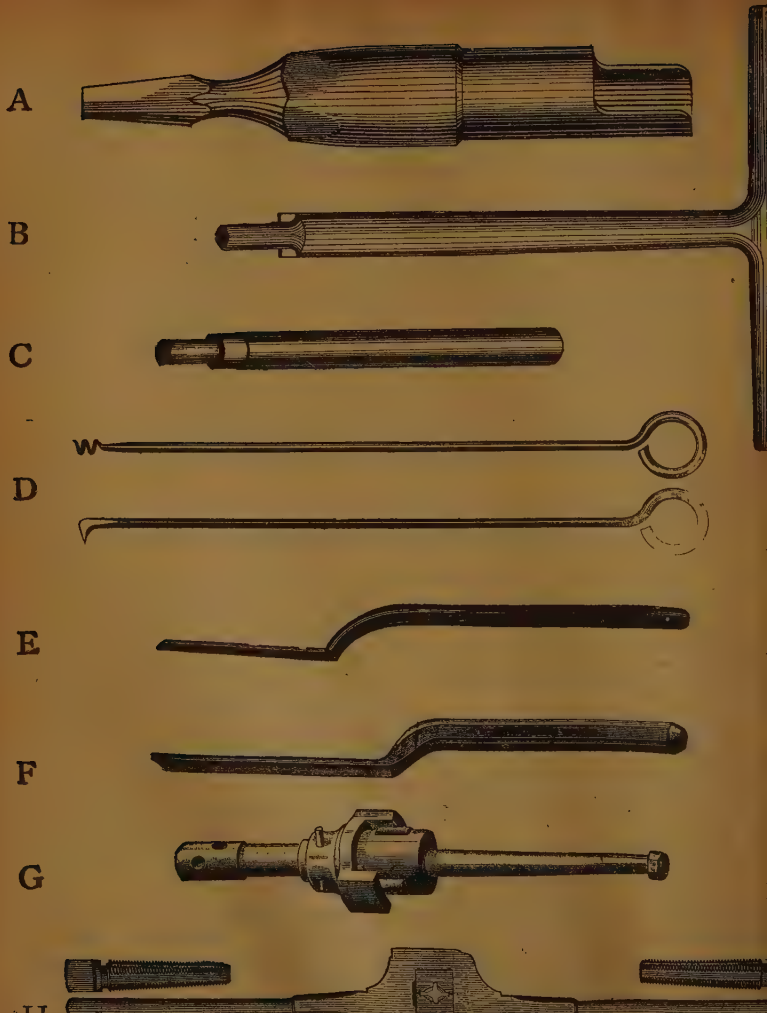
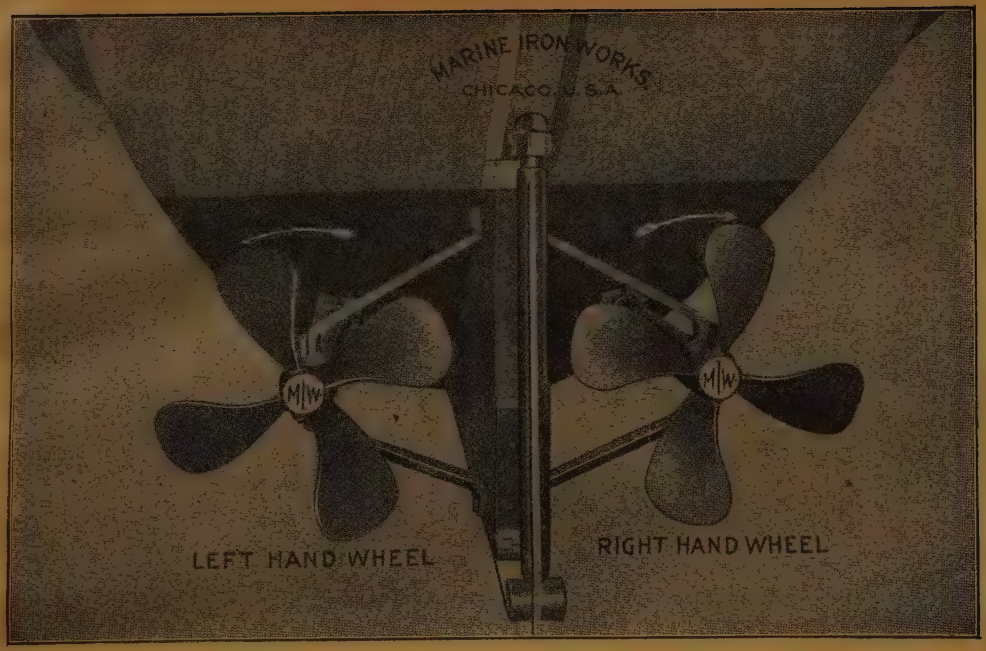


FIG. 119.—Several Tools included in the Outfit of a Steamship. A to D are
denser packing tools and hooks; E, a caulking tool; F, a gasket chisel;
boiler tube expander; H, a set of taps and dies for making male and fe
threads on nuts, bolts and pipes.

PART FOUR.

PROPELLER WHEELS.

CHAPTER EIGHTEEN—PADDLE WHEELS AND SCREW PROPELLERS.



Right Hand and Left Hand Propeller Wheels

When ordering a propeller, the following information should be given to the manufacturer: Size of boat, length, beam, draught; kind of service in which boat is engaged, in other words, is a cruising, towing or speed wheel desired; kind of power; if steam, size and kind of engine, whether single or double cylinder, compound, triple, or quadruple expansion; average working pressure; condensing or non-condensing. If gasoline engine be used, make and size of engine. *Whether engine turns to the* ***right*** *or* ***left.*** The above cut

CHAPTER EIGHTEEN.

PADDLE WHEELS AND SCREW PROPELLERS.

342. What is the office of the propeller?

The propeller is the agent that, under the influence of the power transmitted to it by shafting, exerts, obliquely or directly, a pressure or thrust against the water and thereby, in reaction, pushes the ship ahead.

343. What is required in propellers for exertion of this pressure or thrust?

A certain surface is needed in all propellers to secure sufficient reactionary thrust from the water.

344. What is slip?

Water, being liquid, is easily displaced sideways; if a plane, therefore, exerts a thrust against it, it will recede more or less in the direction of this pressure. The receding is called the slip of the propeller and is usually expressed as a percentage of the advance that would have been accomplished, if no slip had taken place.

345. What influences the magnitude of the slip?

The slip is influenced by the surface and by the speed with which this surface travels through the water.

If a certain pressure is required to propel a ship at a given speed, a large total surface will have less pressure per unit than a small total surface, and the slip will consequently be less. Also, if the speed of the surface is high there will be less time, proportionately, for the action of the surface unit on the water than, with low speeds, and, therefore, less time for

fully overcoming the inertia of the water, and accelerating sternward.

346. Is a small slip considered advantageous for propulsion?

Too small a slip occasions loss of power through excessiv friction. The best economy seems, in the average, to be realized with about twenty per cent. slip.

347. What kinds of propellers are in use?

Aside from the jet propeller, for special cases, the most important propellers of commercial usefulness are:

(1.) Paddle-wheel propellers.

(2.) Screw propellers.

348. What are the characteristics of the paddle-wheel propeller?

The paddle-wheel propeller immerses only the lower pa of the arms with the buckets, while the whole upper part the wheel with the shaft is always above water, giving th convenient access for inspection and repairs with the sh afloat. But the wheels, being built up from a large number parts, bosses, arms, buckets, etc., are exposed to derange ment and injury from floating objects, ice, collision, etc.

For sea service the paddle-wheel has been superseded a most entirely by the screw. The wheels do not work well a seaway on a rolling ship, with one wheel dipping deep ar the other out of water alternately, and they are also very se sitive to large variations of draft that change the dip. The retain their position, however, in smooth and shallow wat navigation, particularly in passenger boats with more or le constant draft and dip. The peculiar stern-wheel form cou hardly be superseded by any other propeller on the shallo draft, where, at the same time, such powerful action is r quired.

349. What are the characteristics of the screw propeller?

The screw propeller is totally immersed for efficient service, being thus inaccessible for inspection and repairs while the ship is afloat. Its shaft connections require stuffing-boxes at

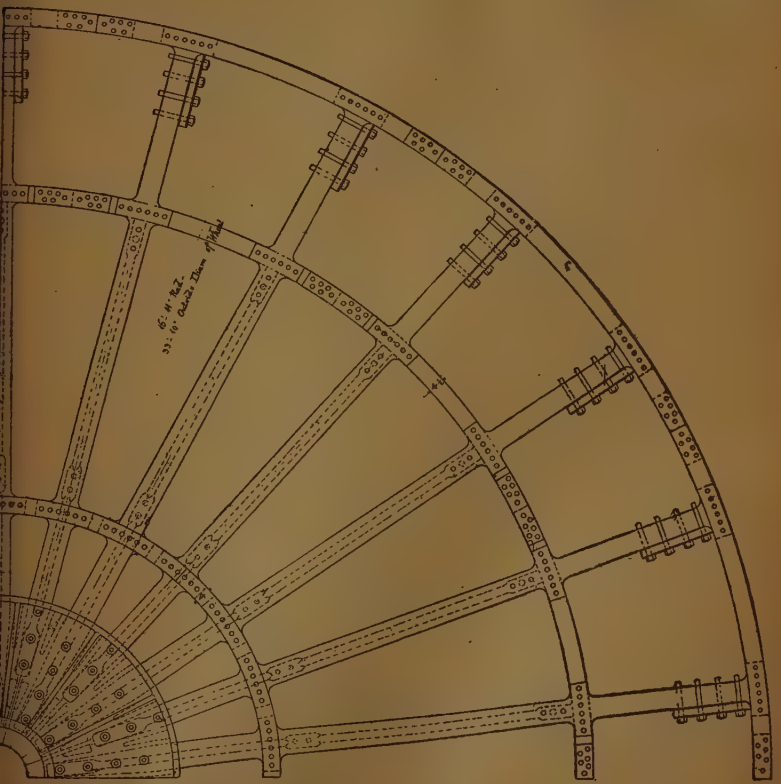


FIG. 120.—Quarter Section of a Radial Paddle-wheel, showing details of construction.

the point of entrance into the ship, but, in spite of this complication, its simplicity makes it quite indifferent to small, floating objects, ice, etc., while its submerged position protects it from outside influences. It is, thus, the propeller

fitted for all sea-going vessels, as it is not influenced by rolling, although somewhat affected by pitching of the vessel and can be used with advantage under greatly varying condition of draft.

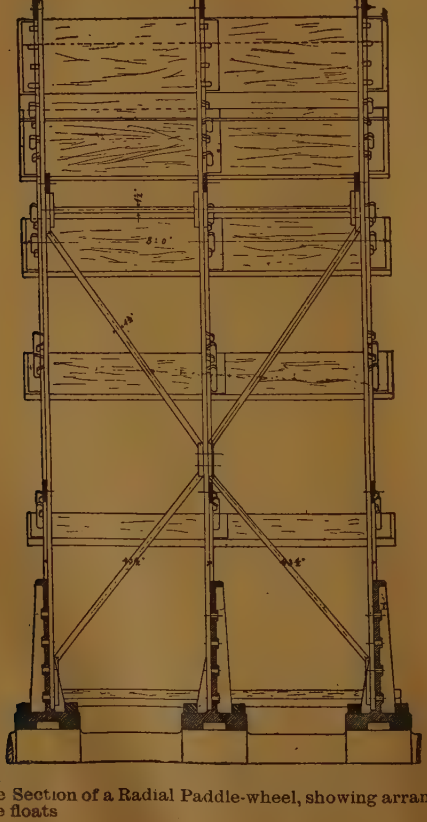


FIG. 121.—Transverse Section of a Radial Paddle-wheel, showing arrangement and metho of attaching the floats

In the arrangement of twin and triple screws, it can b used for fairly shallow draft; such subdivision, at the sam time, preventing a complete breakdown of the machinery.

350. How does the paddle-wheel propeller accomplish its work?

The thrust-exerting surface in paddle-wheels is arranged at the circumference of the wheel, in the form of floats, that are drawn through the water by the revolutions of the wheel.

351. In what direction do the floats exert the pressure against the water?

The floats press horizontally against the water in the central position, depressing it in the entering, and lifting it in the leaving position.

352. Are all paddle-wheels alike in their action upon the water?

No; paddle-wheels can be divided into two classes, according to their action upon the water:

(1.) Radial wheels.

(2.) Feathering wheels.

353. What affects the depressing and lifting action of the wheel on the water?

The dip and the diameter of the wheels affect its action upon the water.

The smaller the dip the less the depression and lifting of the water, and the larger the diameter the less the deviation from the vertical in the same number of floats in the wheel.

354. What are the characteristics of the radial paddle-wheel?

The radial paddle-wheel has its floats, or buckets, immovably fastened to radial arms. It is, therefore, desirable to have the dip as small or the diameter as large as possible for easy entering and leaving of the water by the floats. The dip in good, modern radial wheels is, therefore, only about 12 to 16

per cent. of the outside diameter of the wheel. To secure a good grip upon the water, three or more floats are immersed at the same time, and the distance between them is about three to four feet for average cases.

FIG. 122.—Side Elevation of a Feathering Paddle-wheel, showing details of construction. The figured parts are: The main shaft (1); the bosses (2); arms (3); float brackets (4); floats (5); pivoting pins (6); radius rod (7); king rod (8); eccentric pin (9); bracing (10); rim (11).

The radial wheels are liable to pound upon the water noisily, making a low number of revolutions and a long stroke

engine desirable. Their simple construction, however, enables them to endure heavy service, as the shaft runs through the wheel to an outboard bearing, giving thus substantial fastening and support for several arm bosses.

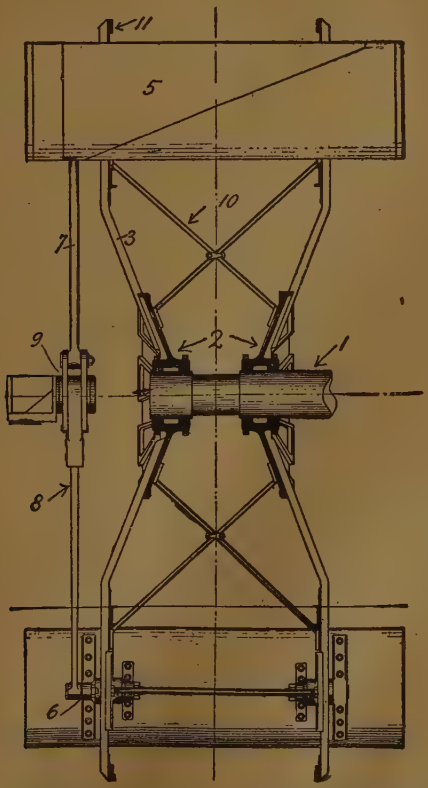


FIG. 123. Transverse Section of a Feathering Paddle-wheel, showing attachments and positions of floats. The numbers correspond to the same parts as in Fig. 122.

There are no movable parts in radial wheels, and the wooden floats are bolted to the arms in a very simple manner that allows an easy repairing or replacing.

355. What are the characteristics of the feathering paddle-wheel?

The feathering paddle-wheel has its floats connected movably to the arm, so that they are guided by levers into a position favorable for exerting the greatest thrust with the least depression or lifting of the water.

This guiding enables the diameter to be quite small, while the dip can have a value of 20 to 24 per cent. of the outside diameter. The distance between the floats is usually about 6 feet.

Feathering wheels work quite smoothly, and are run at a higher number of revolutions than radial wheels. The construction is complicated, owing to the pivoted floats and the moving mechanism of a series of radius rods, one for each float, revolving around a fixed eccentric pin on the outboard side of the wheel. This mechanism does not readily permit the shaft to run through, thus leaving the wheel overhanging on one side of the bearing. Therefore, even with a good diagonal bracing, the wheel is never so rigid as a radial wheel.

356. How are paddle-wheels constructed?

Paddle-wheels are constructed with the following parts:

(1.) Bosses.

(2.) Arms, with rims and braces.

(3.) Floats and their moving mechanism.

357. How are the bosses constructed?

The bosses furnish the connection between the arms and the shaft. They form essentially a cylindrical sleeve, keyed to the round, or octagonal, shaft and discs, for the attachment of the arms, and are made of cast iron, semi-steel or cast steel. To facilitate fitting and repairs, they are often made in halves, with bolted flanges and wrought-iron rings around the sleeves as reinforcement. The discs are stiffened by webs

between which the arms are tightly fitted and bolted to the discs.

For side and stern radial wheels three or more bosses, with straight discs, are fitted for each wheel, while for feathering wheels only two bosses, with inclined discs, are fitted in each wheel.

358. How are the arms constructed?

The arms transmitting the motion to the float are constructed of wood or iron, securely attached to the bosses, united by rims, and held rigidly in position by diagonal braces.

To resist the bending strains of the power transmission they are of rectangular section, with the largest dimension circumferentially. The iron arms have often rim lugs and float pin bearings welded on, or are constructed from shapes, like channels, with riveted diamond plates for rim connections, while the pin bearings are castings of steel, riveted to the arms.

The rims are usually flat bars or shapes, the braces being of round sections, with forged palms for the rivet connections. The wooden arms and braces give the whole structure a certain elasticity and ease of repair, while the iron ones secure much greater strength and longer life. Steel construction is universally employed for feathering wheels.

359. How are the floats and their mechanism constructed?

The floats have to exert the thrust against the water. They should be strong enough to transmit the power received from the arms without bending or buckling. For the floats of radial wheels wooden boards are used, and are usually quite rigid at the desired strength. For feathering wheels, where thin sheet steel is employed, the stiffness of the floats is often obtained by curving them slightly, with stiffening angles on the short edges.

To secure the smallest shock in radial wheels the floats are

fitted in halves, radially or laterally. The so-called "Mahoney" buckets are fitted obliquely between the sets of arms, gaining thereby a more gradual immersion than parallel ones. The wooden floats are clamped to the arms by a hook, or through bolts with washers under the nuts.

The floats of feathering wheels are supported by pins, which complete the hinge connection between the brackets on the float and the brackets on the arms. One of the cast-steel float brackets has a long lever cast on that connects with a pin to the guiding radius rod and, by its position, holds the float, so that it passes through the water nearly square to the direction of advance, with a great gain of power and a great reduction of shock and wear.

The radius rods all connect to a centre, that revolves around a pin placed at a certain distance forward of the centre of the wheel. The radius rods are jointed to this centre by pins, except one, the so-called king-rod, that is rigidly bolted to the centre, carrying it around the pin in a position fixed in relation to the wheel.

The pin itself is attached to the outboard guard beam with a bracket.

The bearings of all pins require a large surface and great strength, as they are not adjustable and are without oil lubrication, while subject to wear and grinding by sand or grit and severe shocks or injury by floating objects.

The pins are fitted with brass sleeves for salt water service, while left without them for fresh water. The bearings are lined with strips of lignum vitæ or Babbitt, preferably in movable sleeves, that allow a quick replacement by spare ones.

360. How does the screw propeller accomplish its work?

The thrust-exerting surface of the screw propeller is provided with radial, oblique blades, that revolve around the centre of the shaft. The blades, through their twist, advance

in revolving as does a screw in a nut. Being totally immersed, every part of the blade is thrusting surface, gaining thus a strong grip upon the water from a comparatively small wheel.

361. How is the obliquity of the blades expressed?

The obliquity of the blades is expressed by the advance that the screw would make in one revolution without any slip, and this axial advance is called the pitch, which is measured in feet. With uniform pitch the obliquity of all parts of the blades

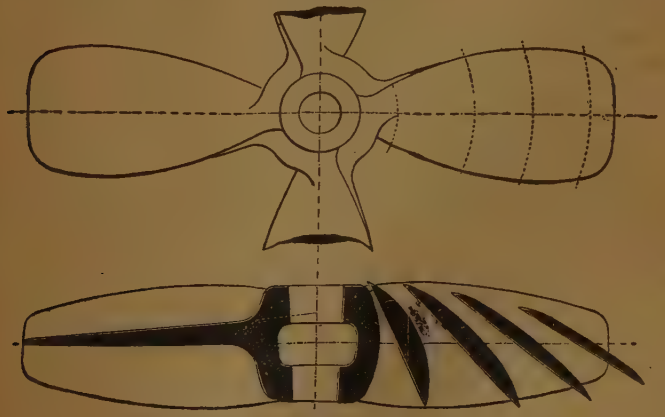


FIG. 124.—Constructional Details of a Screw Propeller.

tends toward the same point, making the twist in all parts near the boss more pronounced than in those near the circumference of the wheel. The pitch is called right hand when an observer behind the wheel and looking forward sees the propeller upon advance turn with the hand of the watch, and it is called left hand if the wheel turns counter to the hand of the watch.

362. To which dimension of the wheel is the pitch proportioned?

The pitch is proportioned from the outside diameter of the wheel, as practice has indicated that the ratio between the

two gives the best working usefulness of the screw. The extreme limits of this ratio can produce no advance of the ship at all, as no pitch would place the blades exactly in the transverse plane, while an infinitely large pitch would place the blade fore and aft, so that, in revolving, they would only churn the water like a centrifugal pump. Intermediate values, making the pitch between one and two times the diameter, are found to produce the best results.

363. Is the pitch always the same for all parts of the blade?

No; screw propeller wheels are built, that have circumferentially or radially increasing pitch.

It is doubtful, however, if they are more advantageous than propellers with uniform pitch.

364. What different kinds of screw propellers are in use?

A great many different characteristics can be made according to

(1.) Number of the blades, as two, three or four bladed.

(2.) Outline of blades, as elliptical, square or other outlines.

(3.) Position of blade on boss, as straight or inclined backward, as curved axially or circumferentially.

There are numerous other small distinctions.

365. Do these differences exert an influence upon the efficiency of the propeller?

A certain style may prove desirable for special conditions but for general conditions they have a very small influence if any, upon the usefulness of the propeller.

The number of blades usually preferred is four for single screw and three for a twin screw arrangement.

366. What are the important points that affect the usefulness and efficiency of the propeller?

The surface should be sufficiently large and so distributed

FIG. 125.—Constructional Details and Blade Sections of the Screw Propeller of the Atlantic Steamer "Deutschland."

as to realize the needed thrust with about 20 per cent. slip a the revolutions best suited to the engine.

The diameter should be large enough to accommodate th needed surface, without crowding the blades too close to gether, and should suit the particular requirements of th ship.

The pitch is determined by speed revolutions and slip, an should be in favorable proportion to the diameter.

367. How are the strength and durability of screw pro peller blades affected by the material?

The materials used for screw propellers are bronze, forge steel, cast steel and cast iron. The strength of the blad should be ample for rigidity, as the outlying parts of th blade, particularly around sharp corners, offer upon deflec tion a greatly increased friction to passage through th water.

Bronze is a material well suited to the construction of a scre propeller. Its strength permits the blades to be quite thin, wit sharp edge, thus offering small eddy resistance to the passag through the water. Its immunity from corrosion through sa water preserves a smooth surface in the water with the lea friction, and gives the blade an almost unlimited durabilit However, upon striking floating objects, its tenacity ma prove undesirable, as the blades do not break but bend, po sibly in such direction as to injure the parts of the hul Forged steel possesses the same advantages as bronze, b cannot be so readily manufactured. Cast steel possesses goo strength, but not much durability, as pitting, particularly o the back of the blade tips, sets in quite strongly, sometim thoroughly honeycombing the outer end of the blade.

Cast iron does not possess great strength and requires construction of much greater thickness, with corresponding greater resistance. Its durability, as regards pitting and co

rosion, proves better than cast steel, but not as good as bronze. An advantage of cast iron may occasionally be its brittleness, as it breaks off clean, upon striking an obstacle, without injury to any part of the hull.

368. How is the screw propeller constructed?

The screw propeller is usually constructed in two ways:

(1.) Loose blades bolted to the boss.

(2.) Blades and boss cast in one piece.

The former type frequently has bronze blades on a cast steel boss, while the latter is usually wholly of cast iron, cast steel, or in small sizes of bronze.

The loose blades permit replacing a damaged blade by a new one, while injury to a solid propeller always necessitates an entire new wheel.

Circular flanges are cast on the loose blades, fitting into recesses of the boss and held by strong studs and nuts. The nuts are set into recesses, over which light cover plates or cement are fitted to make a smooth surface of the boss, with the least resistance in the water.

With the loose blades a small adjustment or alteration of the pitch can be effected by making the flange bolt holes oval.

The casting of blades is done either from a pattern or they are swept up in sand or loam around the centre of the boss. The boss is bored to suit the taper of the propeller shaft, and is usually hollowed by coring, to prevent excessive weight. The forward end of the boss usually fits, water-tight, over the after brass sleeve, to prevent corrosion to the steel shaft.

A conical fair leader sleeve covers the nut on the end of the propeller shaft, preventing corrosion of the end of the shaft and making an easy delivery of the water from the boss.

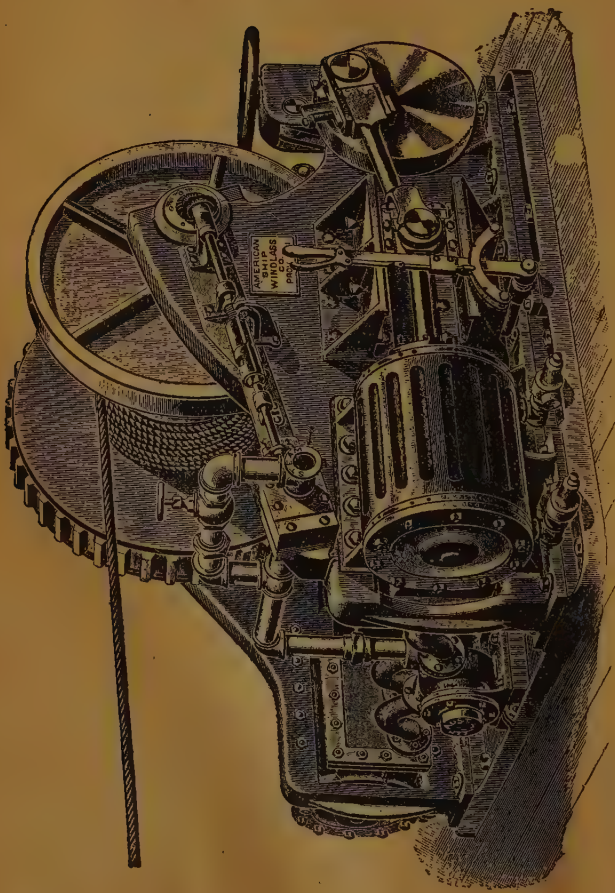
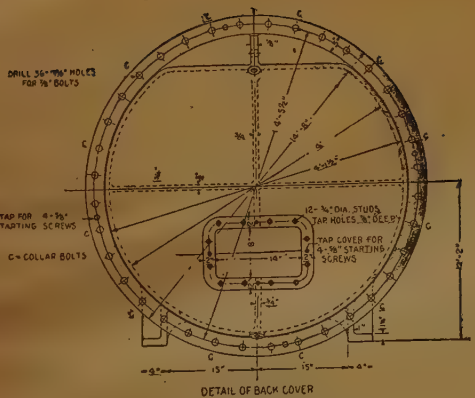


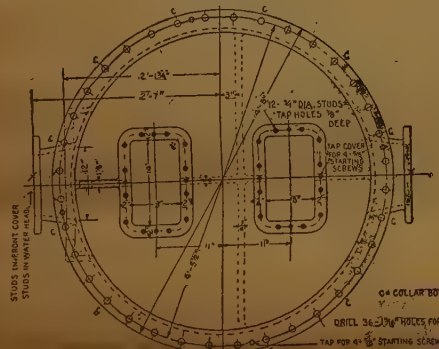
FIG. 126.—A Towing Engine.

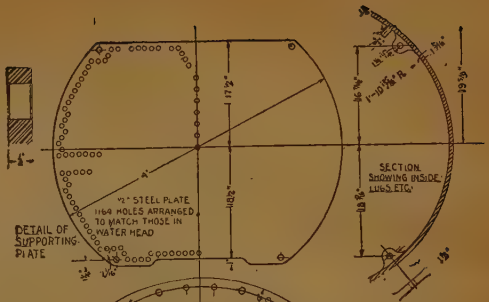
PART FIVE.

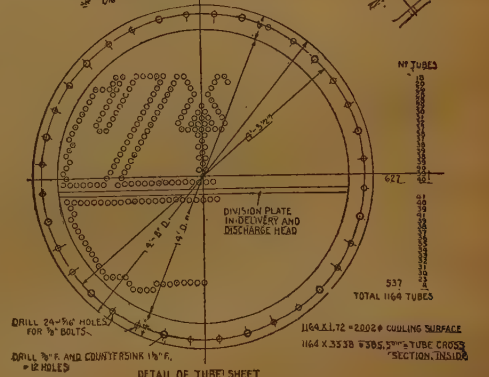
AUXILIARY APPARATUS: THEIR FUNCTIONS AND OPERATIONS.

CHAPTER NINETEEN—AUXILIARY APPARATUS OF A MARINE ENGINE.


DRILL 36-7/16" HOLES FOR 3/8" BOLTS
TAP FOR 4-3/8" STARTING SCREWS
C= COLLAR BOLTS
12-3/4" DIA. STUDS TAP HOLES 3/8" DEEP
TAP COVER FOR 4-3/8" STARTING SCREWS
DETAIL OF BACK COVER


12-3/4" DIA. STUDS TAP HOLES 3/8" DEEP
TAP COVER FOR 4-3/8" STARTING SCREWS
STUDS IN FRONT COVER
STUDS IN WATER HEAD
C= COLLAR BOLTS
DRILL 36-13/16" HOLES FOR 3/8" BOLTS
TAP FOR 4-3/8" STARTING SCREWS


1/2" STEEL PLATE 1164 HOLES ARRANGED TO MATCH THOSE IN WATER HEAD
DETAIL OF SUPPORTING PLATE
SECTION SHOWING INSIDE LUGS ETC.


Nº TUBES
DIVISION PLATE IN DELIVERY AND DISCHARGE HEAD
537 TOTAL 1164 TUBES
DRILL 24-5/16" HOLES FOR 3/8" BOLTS
DRILL 3/8" F. AND COUNTERSINK 1/8" F. 12 HOLES
1164 X 1.72 = 2002 ø COOLING SURFACE
1164 X .3538 = 385.5 TUBE CROSS SECTION, INSIDE
DETAIL OF TUBE SHEET.

Details of Surface Condenser Covers and Tube Sheet

Top and side sectional views of surface condenser assembly is shown

CHAPTER NINETEEN.

AUXILIARY APPARATUS OF A MARINE ENGINE.

369. What is the function of the condensing plant?

The condensing plant cools the exhaust steam from the last cylinder to a temperature so low that it is reduced to water. The water thus obtained occupies a much smaller space than the steam before condensation, leaving a partial vacuum, which is equal to a reduction of the back pressure in the last cylinder.

The water must be removed by a pump, however, to prevent filling up of the condensing plant. This pump at the same time performs the office of removing any air that might easily be disengaged from the water, under a partial vacuum, and, on accumulation, would soon destroy the vacuum.

This pump is called the air pump.

370. What systems of condensation are in use?

Two systems of condensation are employed, according to the advisability of mixing the cooling water directly with the exhaust steam or not:

(1.) Surface condensation.

(2.) Jet condensation.

371. What are the characteristics of surface condensation?

Surface condensation does not mix the cooling water directly with the exhaust steam, but subdivides the condenser into two parts, one for the exhaust steam, the other for the cooling water. The subdivision is thoroughly steam, air and water-tight, and is arranged as a large surface in the form of

tubes, so that the cold water may effectively and rapidl reduce the exhaust steam to water.

The air pump of a surface condenser must remove th accumulated air and the amount of condensed water, while special pump is provided for the circulation of the coolin water over and through the tube surface.

The surface condenser is employed on ships for salt wate navigation, as the condensed water is thus kept fresh, and ca be used as feed water for the boilers, to which under mo ern conditions salt water feed would prove highly injurio and not economical. A surface condenser may prove desi able also in very muddy fresh water, which, if used for fee would fill the boiler with deposit and scale, to the detrimen of the steaming capacity.

372. What are the characteristics of jet condensation?

Jet condensation mixes the cooling water directly with th exhaust steam.

There is only a single chamber in the condenser, into whic the cooling water is passed in form of a spray direct under the entrance of the exhaust steam, securing thorou intermingling of the two.

The air-pump in this case removes the air, the condens water, and also the cooling water.

No special circulating pump is needed, as the excess of th atmospheric pressure over the vacuum forces the wate through the pipe and the spraying nozzle, into the condens chamber. The jet condenser is employed for fresh water na gation, where a part of the water delivered by the air-pum can be utilized for feeding the boiler, without endangering i safety or efficiency, through formation of scale or incrustatio It is extensively employed on the Great Lakes and the rivers the Eastern coast.

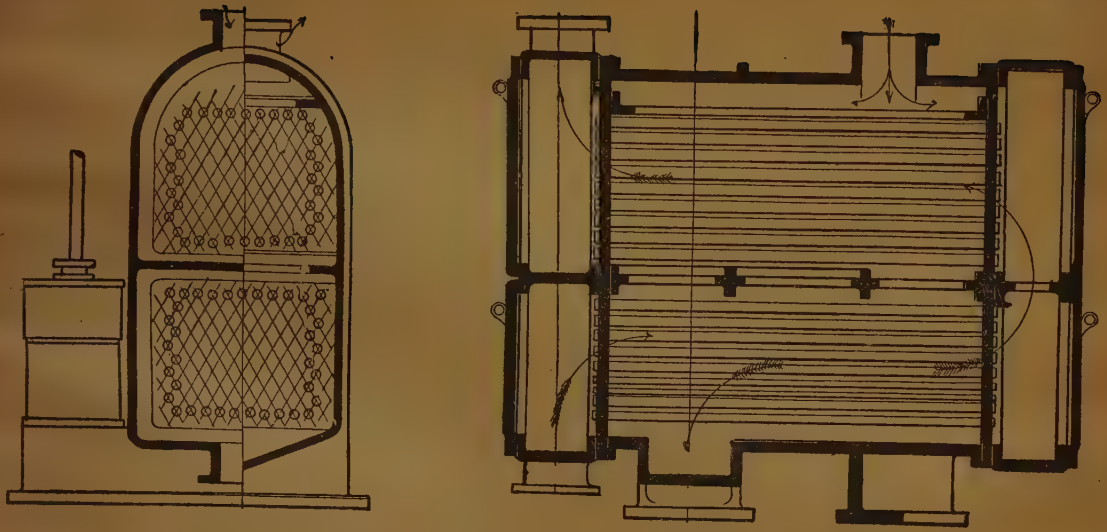


FIG. 127.—Transverse and Longitudinal Sections of a Surface Condenser.

373. What are the arrangement and action of the surface condenser?

The surface condenser is a shell for the reception of the steam, usually of round or box shape. It is traversed longitudinally by one or more systems of tubes ; closed at the end with tube plates for the support of the tubes, and with hollow bonnets or chests for the cold water circulation.

The exhaust steam enters at the top, and after passing over the cold tubes is drawn off as condensed water at the bottom by the air-pump. The steam is directed in its downward passage by baffle plates, which secure a complete utilization at the cooling surface of condensation. A certain space is left in the bottom of the condenser for the accumulation of the water below the cooling surface. Direct touch of the cooling surface would chill the condensed water more than is necessary or desirable for its use as feed water.

The cooling water circulation is arranged through the end covers, so that the coldest water enters at the bottom, meeting the steam at the lowest temperature, and the warmest water at the top, meeting the hottest steam. The cooling water passes through the condenser usually twice, going from the inlet through the lower tube system to the other cover and back to the outlet in the first cover through the upper tube system.

374. What is the arrangement and action of the jet condenser?

The jet condenser is usually a vertical, barrel-shaped vessel that receives the exhaust steam at the top.

The cooling water enters, generally at the side, flowing through an internal tube into the spraying nozzle.

In discharging through a large number of small holes a thorough intermingling with the steam takes place, producing a quick condensation, while falling to the bottom of the condenser for removal by the air pump.

FIG. 128.—A Type of Jet Condenser, with Vertical Independent Air Pump.

The curved internal tube and nozzle are usually of cast iron, with a large flange bolting on the outside to a face of the condenser, thus allowing removal of the tube and nozzle and access to the interior of the condenser.

The injection cock or valve frequently bolts to the same large flange.

375. How is the shell of the condensers constructed?

The shell of all condensers must resist the excess pressure of the atmosphere above the vacuum, and, for this purpose, must be tight and rigidly strong. In jet condensers a barrel-shaped form of cast iron easily provides the necessary strength. The jet condenser is small in size and round in section, which facts allow the necessary strength to be conveniently obtained.

In surface condensers the shell is frequently of cast iron in cylindrical or box-shaped sections, which must be stiffened by ribs and webs on all flat surfaces to prevent collapse.

In modern plants, condenser shells are often built from sheet steel in cylindrical shape, with stiffening rings around them. For naval vessel the shells are cast in brass, or built up from composition sheets, to save weight and prevent corrosion and galvanic action upon an iron shell.

Nozzles are cast or riveted on for the connection of the exhaust pipe at the top and the air-pump suction at the bottom.

Frequently surface condensers are built into and form part of the framing and the bed plate of the engine, in which case the shell has facings, lugs or flanges, for attachment to the other parts of the framing. Where the condenser is independent, lugs, brackets or flanges must be provided for secure attachment to suitable foundations.

The inside space is subdivided by baffle plates to guide the steam in its course over the tubes.

Hand-holes in the lower part are frequently provided for cleaning, fitting, zinc plates, etc.

Nearly all surface condensers have a salt water connection, in order that they may be used as jet condensers, in case the circulating pump should break down.

Surface and jet condensers sometimes have suction connections to the bilge, which allow the air-pump to be used for pumping large quantities of water from the hold in case of a leak of the ship.

To establish a vacuum in a surface condenser, with independently driven air and circulating pump, a steam connection, the "bleeder," is made to the condenser shell. This bleeder also takes care of the steam blown off through the safety valves, to save the steam for fresh water and avoid the noise of blowing off.

Another fitting of the surface condenser is a cock and funnel to inject a soda solution into the condenser. The soda solution upon boiling cuts from the outside of the tubes all fatty and greasy matter, which might decrease their heat-absorbing capacity.

Drain cocks are provided in the lowest parts of the condenser, to prevent injury by freezing of retained water on laying up the machinery.

To neutralize galvanic action that might injure the iron shells, zinc slabs are often fitted in the interior of the condenser.

Cement is sometimes applied to the bottom of the condenser for preservation, as well as for making an easy and free drain to the air-pump suction.

376. How are the tubes constructed and fitted?

The tubes offer a large cooling surface for thorough circulation of the steam over them. Being crowded quite closely, it is advisable to omit some of the rows of tubes, in order to

allow more ready circulation of the steam between them. The excess pressure being on the inside, the circular form is best adapted for this work.

The tubes of modern surface condensers are of brass, frequently tinned, packed in the tube plates to allow for expansion under the heat of the steam. The tubes should not be too light nor too long, to prevent sagging under their weight. If a long condenser is necessary, supporting plates are fitted in the middle of the length of the tubes. The diameters most frequently used are five-eighth and three-fourth inch outside

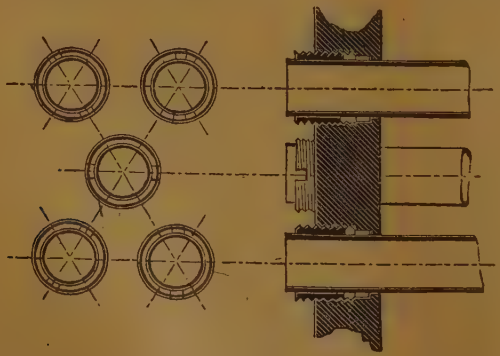


FIG. 129.—Details of Wick and Gland Packing for the Tubes of a Surface Condenser.

diameter. Materials having the least galvanic reaction upon iron are desirable.

377. How are the tube packings constructed and fitted?

The tube packings should be thoroughly tight, while, at the same time, easily made and quickly replaced. The imperative demand for pure, fresh feed water for the boiler has done away with all the cheaper kinds of tube packings, and only two are now of commercial importance:

(1.) Wood packing.

(2.) Wick and gland packing.

The wood packing consists of a small, soft, wooden sleeve, which is pushed into the smooth hole of the tube plate, over the tube end, in a compressed condition. After being wet by the steam and water, it swells considerably, thus clamping the tube tightly on the inside, while pressing strongly against the tube plate. Outside of the tube plate, where free to swell, it should form a slight collar around the opening.

With sufficient previous compression, the wood sleeve proves amply able to preserve a tight joint. It has the advantage of being cheap, easily made and quickly applied, but

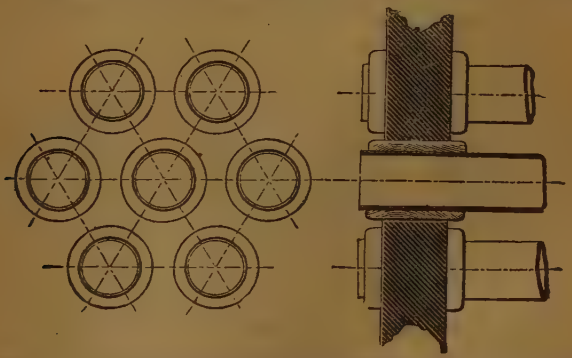


FIG. 130.—Details of Wood Packing for the Tubes of a Surface Condenser.

it is reported that it does not prove very durable after long periods of inactivity of the condenser.

The wick and gland packing requires a recess in the tube plate, around the tube opening, tapped for reception of a screwed gland that slips over the tube end, compressing into the bottom of the recess several strands of lampwick packing, which cramps the tube tightly.

The outside end of the gland is sometimes contracted, thus preventing the tube from crawling out of the tube plates.

The gland packing is expensive and somewhat tedious to make, but proves in the end the more durable and lasting

variety. The condenser is always ready to commence work again, even after long laying-up.

378. How are the tube-plates arranged and fitted?

The tube-plates support the tubes and provide for the water-tight access of the circulating water to the inside of the tubes. At the same time they close the ends of the shell steam-tight, being attached to the shell flanges by numerous bolts, preferably made of brass or Tobin bronze, to prevent corrosion.

The tube plates are now almost universally of brass, thick enough to afford a good bearing for the tubes and their packing, and strong enough to stand the excess pressure of the atmos-

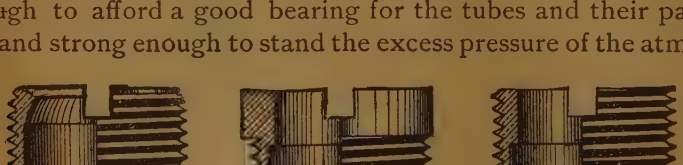


FIG. 131.—Three Styles of Screw-gland for Packing the Tubes of a Surface Condenser.

phere without deflection. For large tube plates stays may be necessary to secure the needed rigidity.

379. How are the water chests arranged and fitted?

The water chests guide the circulating water to and from the tubes. They are under no excess pressure, except from the head of the water outside of the ship, and are, therefore, easily kept tight in the tube joints and around the flanges, which are generally fastened and held to the shell by the same set of bolts that hold the tube sheets. For the common arrangement of two nests of tubes, with the water returning to the first chest, there must be a substantial sub-division into inlet and outlet chamber, while the back chest contains but one space.

Care should be exercised that the circulating water passes, as far as possible, through all the tubes.

The chests should contain no pockets for possible accumulation of air or dead water, which would prevent the circulation, and allow the steam to heat the affected tubes and spoil the vacuum by leakage. Air and drain cocks should be provided, so that a complete removal of air, while used, and of water, when unused, may be effected.

Hand and peep holes, as well as large covers, in the front of the chests are fitted to give access to the tubes, without removing the whole chest. Chests and large covers are fitted with lugs for lifting appliances, which greatly facilitate the removal.

380. What special forms of condenser are found in marine practice?

A special form of jet condenser is the ejector condenser, a nozzle system of the injector type.

Some forms of surface condensers attempt to do away with a special circulating pump, and circulate the cooling water over the condensing surface by the velocity of the ship.

In small launches the whole condenser of pipe form is hung outside the boat alongside of the keel. In larger boats of high speed a scoop, on the outside of the hull, throws the water through a pipe of easy lead, through the tubes and out of another pipe in the after part.

381. What is the duty of the air-pump?

The duty of the air-pump is to remove the air and water from the condenser. In jet condensers it also removes the condensed water and the cooling water, while in surface condensers only the condensed water is pumped.

The jet condenser air-pump must, therefore, pump and remove a much larger quantity of water and air than the

air-pump of the surface condenser, and is for this purpos larger, unless the latter is arranged to work jet-condensing i an emergency.

382. What type of air-pump is generally used?

The vertical, single-acting air-pump is generally employe

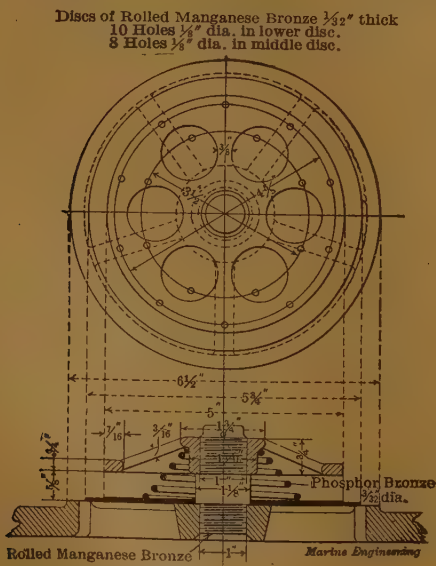


FIG. 132.—Detail of Improved Air Pump Valve, as used on the U. S. Cruiser "Denver" indicating constructive materials and dimensions.

as the most efficient type; it has entirely superseded th horizontal, double-acting pump formerly used.

383. What are the parts of the vertical air-pump?

(1.) The barrel, the suction channel-way and the cover wit delivery channel and hot well.

(2.) The bucket, or piston, with its valves, the foot-valve and the head-valves.

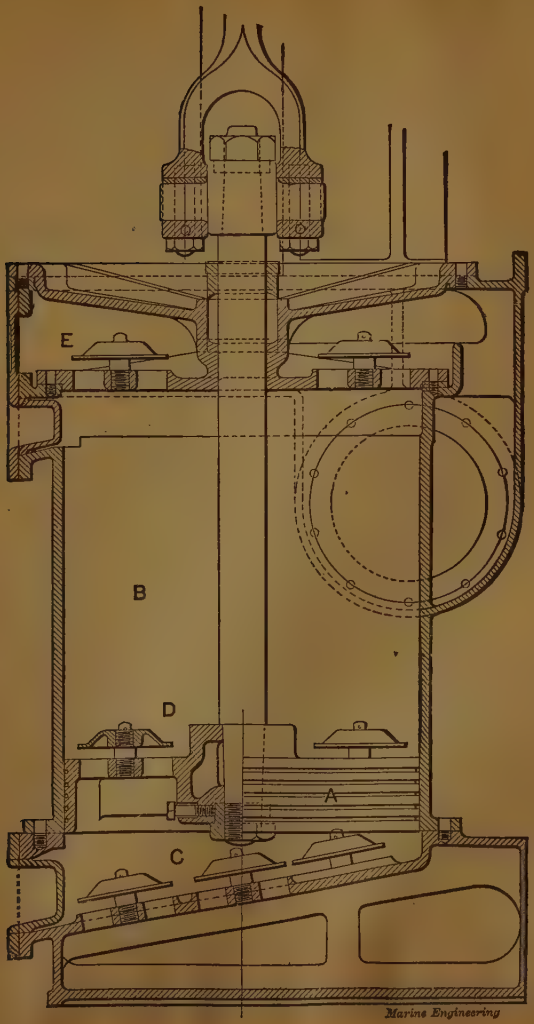


FIG. 133.—Vertical Air Pump Used in Connection with the Condensers of Marine Engines The lettered parts are: A, the bucket or piston; B, the barrel; C, the foot-valves; D, the bucket-valves; E, the head valves.

384. How are the stationary parts of the air-pump constructed?

The suction channel-way is arranged at the lowest part of the condenser, so that the water can be readily and completely removed from it. It is often a part of the condenser shell or otherwise bolted to it; and, being usually of cast iron, must be strong enough to withstand the full atmospheric pressure. As it usually supports the foot valves, all joints and valve-seat division plates should be fitted in a thoroughly air-tight manner.

The barrel connects generally to a flange or facing of the channel-way, and is constructed in composition or cast iron, with composition sleeve tightly rolled in. It is bored truly cylindrical on its working face, with slight recesses at top and bottom, similar to a steam cylinder, for the over-running of the piston or its rings.

For quick access to the bucket or foot valves, a hand-hole cover is often fitted above or directly in the bore of the barrel, in order to avoid dismounting the top-cover and head valves—a great saving of time and labor to the engineers.

The delivery channel is sometimes cast on to the barrel, or, together with the cover, is bolted to the top flange of the barrel. It holds the head valve seat, which, however, is also found independent and bolted directly to the top flange of the barrel. Cast iron is extensively used for it, although the United States Navy requires composition.

The vertical extension for the accumulation of the discharge water is called the "hot well," from which the feed pumps draw their supply. An overflow is provided to discharge the surplus to the outside, or to the feed tanks, which is quite an important operation, with jet condensers, but to be avoided with surface condensers, as all the fresh water from the air pump is needed for feeding the boilers.

FIG. 134.—Type of Vertical Twin Independent Air Pump.

385. How are the working parts of the air-pump arranged and constructed ?

The valves of the air-pump have the greatest influence on its efficiency.

They should be arranged so as to pass all water easily and readily, and open or close quickly with any difference of pressure. The clearances between them and the reciprocating piston should be as small as possible, and without pockets that might retain air. A small amount of water should stand upon them, so that a possible leakage would be of water instead of air.

In the valves rubber is usually the material employed, although metal valves are used in the Navy. Rubber valves are light, open readily, and make a good, tight joint, but, since mineral oil is used in engine cylinders for lubrication, the ordinary rubber deteriorates under its influence, and repairs are liable to be frequent.

On account of their greater durability, metal valves are employed. Also hard rubber or fibre valves justly enjoy a certain popularity, as being much more durable than those made of soft rubber.

In form the valves are either single rectangular flaps, which lift up on one edge against a curved metal guard, or are formed by several smaller circular valves, rising bodily from their seats. To secure a quick closing, springs of bronze wire are sometimes fitted on them.

The valve seats are usually independent and constructed of composition.

For the round valves a central stud keeps the valve in place allowing only lifting movements, which are limited by a guard at the top of the stud.

The flap valves are clamped to the seat on the stationary edge by their curved guards.

The piston or bucket of the air-pump is actuated either by a

solid piston rod, or by a hollow trunk, made entirely of composition, or covered by a composition sleeve. The piston rod type must have a connecting rod and guides above the top cover, while the trunk type contains the connecting rod bearing in the trunk near the piston, and requires no extra guides.

The bucket carries the bucket valves, which allow the air and water to pass to the delivery side. The tightness of the bucket against the side of the barrel is secured by a very broad, solid piston, with water grooves to stop leakage, or, more commonly, by packing. This packing may consist of one or more split metal packing rings, bearing, by their elasticity, against the walls, or of fibrous or soft material, held in place and compressed by a bolted follower ring. A stuffing-box is provided in the top cover for water-tight passage of the piston rod or trunk. With the large diameter of the trunk the depth of the stuffing-box should be ample, as the packing cannot be compressed as uniformly as around a small rod.

386. What is the function of the circulating pump?

The circulating pump forces or draws the cooling water through the tubes of the condenser.

As the discharge is usually near the surface of the contained water, but little work, in actually lifting the water, must be done by the circulating pump, which, as its name implies, only produces circulation. It is for this purpose that the centrifugal pump is so well adapted, as it runs smoothly, always in one direction, and can pass large quantities of water with low pressure in the pipes and chests. Reciprocating pumps have been entirely superseded on this account.

387. How is the centrifugal circulating pump arranged and constructed?

The centrifugal pump has very little suction power, and is preferably placed all below the water line, that it may remain

full of water. It is usually made of composition metals, in order to avoid all perceptible corrosion, or galvanic action, under the influence of the sea-water. It consists of a casing, with inlet and outlet nozzles for the pipe connection, and stuffing-boxes for the shaft and the runner, or wheel, with its shaft.

The casing is essentially a spirally enlarging space, in which the water is accelerated and delivered from the central inlet to the circumferential discharge. The inlet is sometimes on one side only, but preferably on both sides, thus avoiding an end thrust upon the runner and the shaft. The casing is split horizontally or vertically, to allow for the entrance of the runner and shaft, and the halves are fitted with flanges for bolt connection. The casing generally has an air-cock at the top for letting out any air that may accumulate there.

With centrifugal pumps not wholly below the water line, a filling-up funnel, or pipe, is sometimes fitted for charging the pump with water. Brackets for the attachment to foundations or engine bed-plate are provided for secure attachment of the pump.

The runner, or wheel, is a disc keyed to the shaft with a boss, and fitted with vanes to transmit motion to the water.

The wheel is usually made of composition, on a shaft of the same material, or of steel covered with composition sleeve. The shaft has bearings, sometimes on one side of the wheel only, next to the stuffing-box, sometimes on both sides. The bearings are frequently lined with lignum vitæ strips, as best adapted to water lubrication.

388. What is the distinction between independent and and connected auxiliaries?

Independent auxiliaries are driven by their own steam cylinder and piston, while the connected auxiliaries are driven by

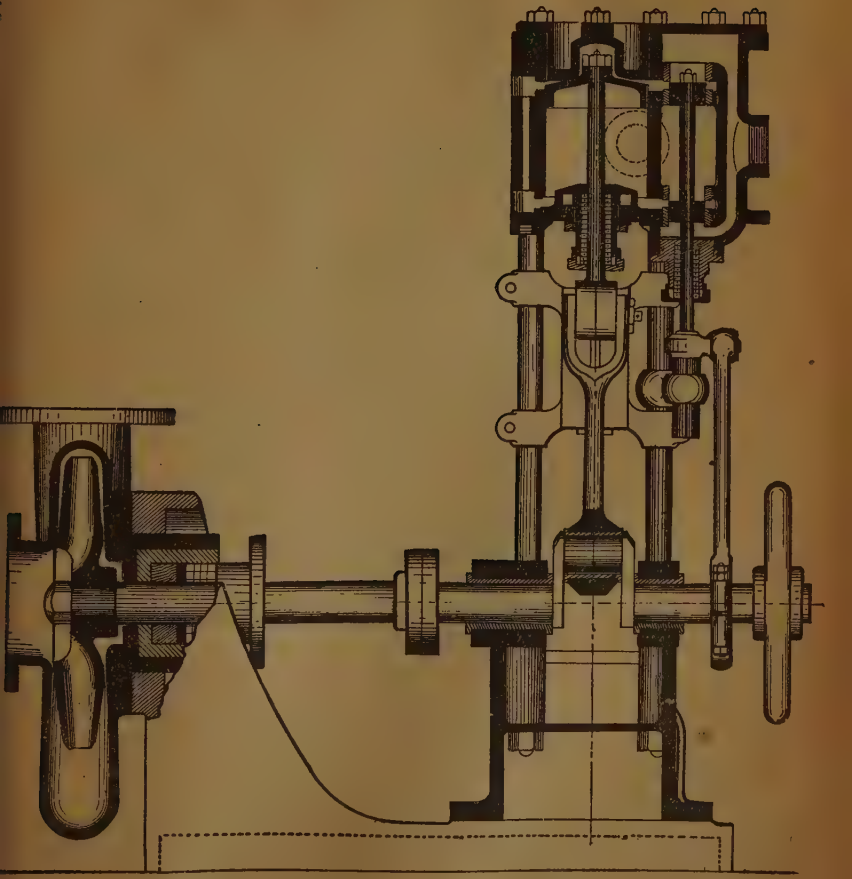


Fig. 135.—Circulating Pump and Engine.

the main engine through a suitable transmission gear, like rocking levers, small cranks or screw and worm gear.

389. What are the characteristics of the independent auxiliaries?

The independent auxiliaries, as their name designates, depend upon no other machine for their motive power. As soon as steam is up in the boilers they are ready to begin work.

Thus the boilers can be fed, the bilges pumped and condensation established, by passing steam into the condenser, circulating the cooling water through the tubes by the centrifugal pump, and removing the condensed water by the air pump. This gives the engineer a great independence and convenience in the operation of the engine, as every auxiliary can be adjusted exactly to its best working condition and efficiency. A drawback, however, results from the greater number of steam cylinders, pipes, joints and connections requiring care and attendance in port, as well as on the voyage, thus greatly increasing the duties of the engineer.

The economy of the numerous small steam cylinders is very low as regards steam consumption, and this also is specified as an objection to the system. Two types of independent steam power application are in use:

(1.) Those operating by reciprocating motion only.

(2.) Those operating by reciprocating and revolving motion combined.

The first type includes those machines in which the steam piston drives a working piston directly back and forth, like all direct-acting pumps. The second type comprises those machines in which the reciprocations of the steam cylinder are transmitted through a connecting rod to a crank shaft which, in turn, sets the working machine in motion. The centrifugal, circulating pump, the turning engine, the blowers

the ash-hoister, the dynamo, the steam steerer, the winches and the windlass are examples of this type.

390. What are the characteristics of the connected auxiliaries?

The principal characteristics of the connected auxiliaries are the absence of all steam cylinders, with their working and transmitting gear. The great saving of attendance and avoidance of uncertainty of operation is, for many engineers, a point in favor of the system.

A second consideration is the application of the power of the main engine to the work of driving the auxiliaries, where it is done at the best possible economy in steam consumption. The regularity of reciprocations is an advantage for certain auxiliaries, particularly air pumps, while the lack of adjustment to variation of the load may prove wasteful, each auxiliary being always run at its greatest capacity.

391. What auxiliaries are connected to the main engine?

The connected auxiliaries, driven directly by the main engine, include, in the older vertical engines, the air pump, a reciprocating circulating pump, feed pump and bilge pump.

In beam engines the air, feed and bilge pumps are usually driven from the beam, while the circulating pump is of the centrifugal, independent type.

In modern vertical or inclined engines frequently only the air pump is driven by the main engine, although occasionally engineers prefer to have a feed and a bilge pump also so connected.

392. How are the connected auxiliaries driven from the main engine?

The connected auxiliaries are commonly driven by a system of rocking levers, or beams, which may be the main walk-

ing beam, as in the beam engine, or special ones, fitted fo this purpose in vertical and diagonal engines.

Occasionally some pumps are found driven by the cran shaft, either with a special short-stroke crank pin, or by helica gearing, for reducing the revolutions to a desired point.

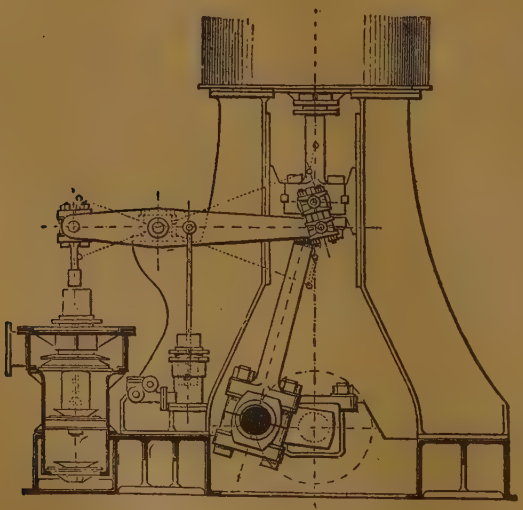


FIG. 136.—Diagram Showing the Connections of Air and Feed Pumps to the Cross-head o the Engine.

The rocking beams transmit the same number of reciproca tions, but reduce the stroke of the pumps by a shortening o the lever on the side of the fulcrum.

The beams are built up of steel plates, cast-iron bosses an centre sleeves, with steel or iron shafts and pins.

The fulcrum pins rest in substantial bearings on the fram ing or foundation, while the end pins carry suspension or con necting rods, for connecting to the engine and pump cross heads or trunk-pins.

393. To what operation are most of the auxiliaries devoted?

Most of the auxiliaries are devoted to pumping operations, or the transportation of liquids or air from or to receptacles. They often stand under pressures varying from nearly an absolute vacuum to the highest steam pressures employed.

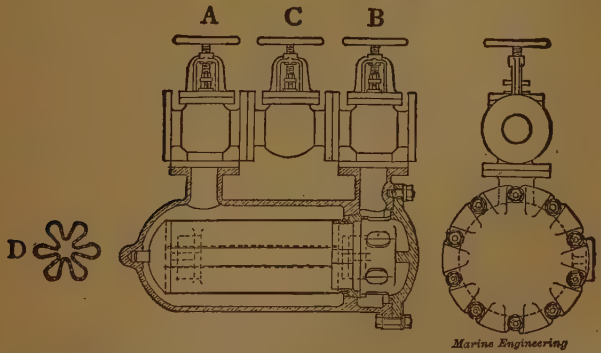


FIG. 137.—A Type of Filter or Grease Extractor used with a Marine Engine. The function of this apparatus is to separate grease and oil from the boiler feed-water. It consists of an iron or gun-metal casing, divided into two compartments by a "diaphragm." This "diaphragm" has a perforation with a collar for supporting the separating cartridge, an iron or brass tube, perforated through its entire length with small holes, and shaped as shown at D. When set in place it is covered with cloth. The feed-water is admitted at the inlet, A, flowing through the cartridge into the second chamber of the casing, and emerging at the outlet, B. C is a by-pass valve, which is opened when A and B are closed for the cleaning of the filter.

394. How is this pumping operation performed?

Pumping operations are mainly performed by a power application:

(1.) To revolving wheels, as found in centrifugal pumps and blowers.

(2) To reciprocating pistons, as found in air and feed pumps.

Special cases are the pumping operations by injectors and ejectors, where the momentum of a jet of steam, issuing through a system of conical nozzles, imparts motion to water drawn through the nozzles.

Another type is represented by the pulsometer, in whic the steam pressure directly exerts lifting pressure upon th water, while the suction action is produced by the condens tion of the steam in the chamber.

395. What are the characteristics of the revolving whe pumps?

The revolving wheel pumps effect the transportation their working fluid by centrifugal force, which is derived fro the continuous revolving wheel. The impelling pressure the centrifugal force is not very strong, and, since retainin valves are entirely absent, the pumping in these machines suited only to light pressures. Under the continuity of flo however, fairly high speed can be given to the working flui and the revolving wheel pumps are thus best suited to pum large quantities against low pressures.

396. What are the characteristics of the reciprocatin piston pumps?

The reciprocating piston pumps give impelling force to t working fluid by the reciprocation of a tightly-fitting pisto acting like a steam cylinder piston. To prevent the return the fluid through the inlet or outlet openings, upon reversal the motion of the piston, automatic valves opening only one direction are fitted over each of the openings.

As the piston and the valves may easily be constructed great strength and tightness, reciprocating pumps are, ther fore, well adapted to transport the fluid against high pressur Reversal of the motion and the more contracted passag through the automatic valves form important objections to high speed of the working fluid, and for this reason recipr cating piston pumps are best suited to raise limited quantiti of water against high pressure, or where a high degree tightness must constantly be maintained.

397. What is the action of revolving and reciprocating pumps?

All pumps effect the transportation of their working fluids by establishing a difference in pressure between two points in their system. The working fluid will immediately try to re-establish equilibrium, and flow toward the point having the lesser pressure. Thus, the air in the condenser will immediately expand into the vacuum produced by the lifting of the air-pump bucket, even if it has to lift valves or pass through crooked channels. In like manner, the weight of water in the centrifugal, circulating pump, being thrown out by the revolutions of the wheel, will leave the weight of the water in the pipes above the pump entirely unsupported, and this will rush immediately toward the pump, to re-establish the balance. This action will produce in the revolving wheel pump a continuous, steady flow.

In reciprocating piston pumps the action is not continuous, since the piston coming to the end of its stroke stops and then returns. Here the action of the automatic valves comes into play.

398. What is the action of the automatic pump valves?

The automatic pump valve can open only one way, and does so only when the excess pressure is below its seat, while, when the excess pressure is above, it will close still tighter. The weight and friction of the valve, however, will consume a certain amount of the pressure before any lifting can take place. Thus, a valve of ten square inches exposed area, weighing ten pounds, would require a pressure of more than one pound per square inch for lifting. For valves totally immersed in water the effective weight of the valve would be the difference between the weight of the valve and the weight of the water displaced by the valve. To make valves lift easily and quickly they should, therefore, be as light as possible, without sacrificing either strength or durability.

The difference in pressure is established by the receding of the piston from its starting point, increasing the volume and decreasing the pressure in the same proportion, similar to the action of the piston in the steam cylinder. Thus, if the clearance space between the piston and the automatic valve is filled by ten cubic inches of air of 14.7 pounds absolute pressure, and if this space is increased to 73.5 cubic inches, then the pressure would be only two pounds per square inch, and there would be 12.7 pounds excess pressure below the valve, which would push the valve open and fill the space with additional air until equilibrium has been nearly established. Upon the return stroke, and consequent compression of the air, the pressure would rise and close the first valve. If a second valve, opening the other way, leads into a pipe or other vessel, then the contents of the piston stroke could, upon sufficient compression, overcome the resistance of this valve and discharge into the next space, pipe or vessel, continuing the operation in this manner. Thus, the first, or suction, valve opens on the up stroke, and the second, or delivery, valve discharges on the down stroke.

399. What is the maximum pressure that a pump can produce by suction under an automatic valve?

As the vacuum is measured below the atmospheric pressure of 14.7 pounds per square inch, absolute pressure, the maximum suction effect must be less than 14.7 pounds per square inch, and is, even in the best pumps, no more than about 12.75 pounds per square inch, or 26 inches in the usual measure of vacuum, the height in inches of a column of mercury.

400. What is the maximum pressure that a pump can produce by compression under an automatic valve?

The pressure of the delivery side of the pump is limited

only by the strength of the pump, valve boxes, valves and pipes and the tightness of the stuffing-boxes and joints.

Feed pumps for water-tube boilers may have to exert as much as 300 pounds per square inch pressure above the atmosphere.

401. Which are the important points for efficiency?

The important points for the good working condition of the pumps are:

(1.) The position of the valves, which should be near to the piston or bucket, thus reducing the clearance as much as possible.

(2.) A straight, easy lead of the pipes and the passages through the pump is highly desirable.

(3.) No air should be retained in any pockets of the pump chamber, as this would seriously interfere with the suction action of the pump.

Air vessels on suction and delivery pipes can greatly reduce water hammer and noise, collecting at the same time the air and gases that are highly undesirable, and, in feed water, even injurious. Pet-cocks are often fitted to ease the pumps by admission of air where air vessels could do the same service with better results.

(4.) If hot water has to be handled by the pump, the supply should flow, under some pressure, to the pump, as the vapor that would be produced might entirely defeat the suction action of the pump.

(5.) The sizes of the pipes and areas of the valves should be such that the velocity of the fluid in its flow should not be too high, a limit frequently found being about 200 feet travel per minute.

Higher velocity is apt to produce water hammer and loss of power through excessive friction.

402. What influence have the size and the lift of the valv on the workings of the pump ?

The required area for passing the fluid at a desired veloc may be obtained either in one or in numerous openings.

If, for example, a valve opening four inches in diameter sufficient for the purpose, then four valves of two inches sixteen valves of one inch will perform the same service at t same speed of the fluid.

To secure, however, an equal area around the circumf ence of the valve the four-inch valve must be lifted one in while the four two-inch valves must be lifted each half inch only, and the sixteen one-inch valves must be lifted o quarter of an inch only.

To secure the desired rapid action of the valves at the e of each stroke, a small lift is highly desirable, as a full openi and closing of the valve is secured with little acceleration b small weight of the valve in its short travel.

403. How are the pump cylinders and their parts arrang and fitted ?

Pump cylinders are, for marine purposes, preferably ranged in vertical position, as taking less floor space, work more satisfactorily and being easier of access.

They have a bored barrel of cast iron or composition which the piston reciprocates, with heads at each end, one them being fitted with a stuffing-box for the piston rod.

Ports from each end, in case of double-acting pumps; fr one end, in case of single-acting pumps, lead to valve bo that contain the suction and delivery valves.

In air pumps the valves are usually arranged directly ab and below the barrel, in order to reduce the clearance spa

The valve-boxes have removable covers that allow the ting of the valves and seats, as well as a ready access to th upon derangement.

Flanged or screwed nozzles serve for the connection of suc-
on and delivery pipes.

A useful fitting, particularly on high-pressure pumps, is a
lief valve, loaded by springs, somewhat above the working
essure, which will allow the water to pass back to the suction
pe if the delivery pipe is shut off. The valves are generally
bronze for high-pressure pumps, like feed and fire pumps,
hile often of rubber for bilge and low-pressure pumps.

A special third-valve system is arranged in vertical air-
mps, where the head valves relieve the bucket valves of the
ad of the atmospheric pressure on the down stroke, with ad-
ntage to the holding of the vacuum.

The pistons are usually of cast iron or bronze, fitted with
ne and nut to the piston rod, and carrying packing rings on
e circumference to secure tightness against the wall of the
rrel.

4. For what purpose are pumps employed on shipboard ?

Aside from the air and circulating pumps of the condensing
ant, pumps are employed for

(1.) Feeding the boiler.

(2.) Emptying the bilges and tanks.

(3.) Supplying water for deck-washing, fire-extinguishing,
aporator and sanitary service.

A special pump for each separate purpose is not always sup-
ed, but one pump may have the necessary pipe connections
serve alternately different obligations.

Feeding the boilers is so important an operation that a
ecial pump is always required. To make absolutely sure of
ample supply of feed water one of the other pumps is made
ong enough to serve the same purpose, or sometimes an in-
tor is fitted as auxiliary feeding mechanism.

A bilge pump is also often fitted specially, for the reason
at it handles very dirty water, undesirable to be transmitted

to any other pipe system. In small ships, however, one pur the so-called "donkey," often serves for nearly all other p poses, including auxiliary boiler feeding.

A special form of pump in use in Western river steamers the so-called "doctor," an independent pump, with a walk beam, through which the steam cylinder drives a system pumps for feed, fire and bilge pumping purposes.

405. How is the feed pump arranged ?

The feed pump should be of simple construction, gr strength and ample capacity, to secure great regularity a reliability of service under the severe conditions of high pr ure.

The main and auxiliary feed pumps are often duplicat This is a desirable point, as one set of spare parts in pist rings, valves, etc., is suitable for both pumps.

The main feed pump is, even in the independent type, of placed in the engine room, while the auxiliary pump, or injector, is in the fire room. The feed pumps draw usua from the hot well, feed heater, and the feed tanks, and charge only into the feed check on the boiler. The feed wa may pass through filters, for collection of oil and impurit and to get rid of any admixture of air, thus saving the boil from scale and pitting or corroding influences.

406. For what purpose are feed heaters employed ?

Feed heaters are employed for the purpose of heating water before admission to the boilers, thus saving the boil from strains of unequal expansion and increasing steam p duction. The heating agent is nearly always exhaust, in mediate or boiler steam, either directly mixed with water, or otherwise transmitting its heat through a tube syst similar to a condenser. In the direct system two f pumps are frequently fitted, the first one pumping the f

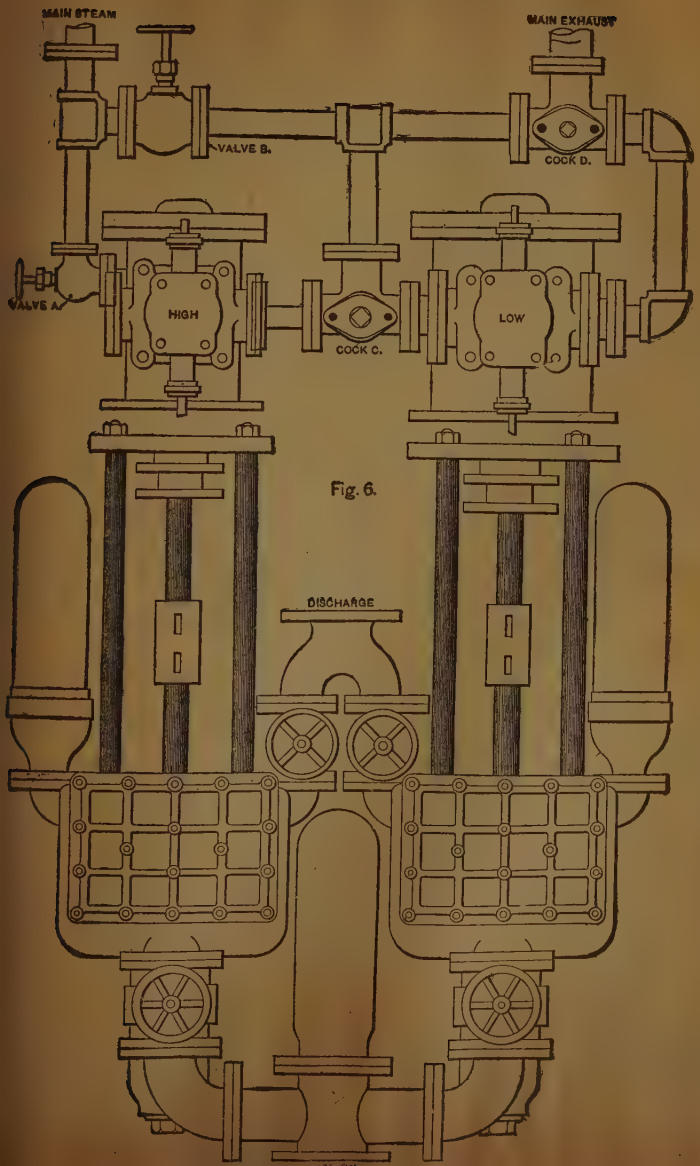


FIG. 138.—Details of the Feed-pumps, Showing Pipe Connections.

water from the hot well to the elevated mixing tank, f
which the second one draws the hot water under pressure
delivery to the boiler.

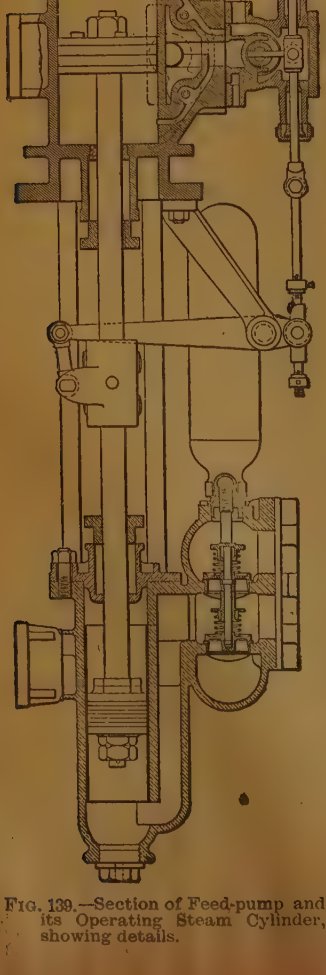


FIG. 139.—Section of Feed-pump and its Operating Steam Cylinder, showing details.

**407. What is the action and c
struction of the injector**

Injectors are used for small o
condensing marine engines. T
work best with cold water
small suction lifts, and are usu
made all of brass or bronze in b
and nozzles. They have a st
inlet continued in the nozzle
side suction for water, a deli
to the boiler and an overflow no
for allowing the water to be
charged upon the starting and
fore the jet of water has acqu
sufficient momentum to lift
check valve on the boiler.

**408. How are the bilge and
last pumps arranged?**

The bilge and ballast pu
should be of large capacity, as
are called upon to pump large q
tities under small pressure, us
only the head of water, due to
draft of the ship.

They have a very elaborate
tem of piping and manifolds, t
able them to draw from all
partments of the ship. Being p
in the engine room, together

heir manifolds, they are under the direct care of the engineer. For large ships they are nearly always independent.

Bilge and ballast pumps should be arranged low in the hold of the ship, in order to have as little suction lift as possible, in their long and complicated systems of piping.

109. How are the ejectors arranged and constructed?

The ejectors are steam jet pumps, often used for bilge pumping purposes, and are usually arranged directly in the

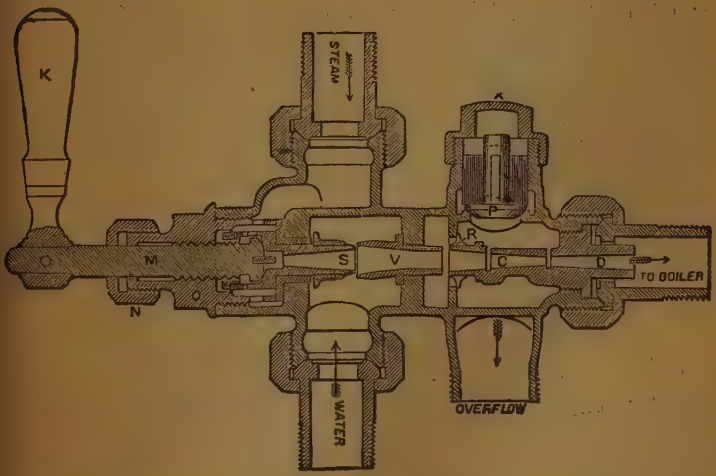


Fig. 140.—Construction of one Type of Injector. S, steam jet; V, suction jet; C-D, combining and delivery tube; R, ring or auxiliary check; P, overflow valve; O, steam plug; M, steam valve and stem; N, packing nut; K, steam valve handle; X, overflow cap.

compartment, with a steam pipe leading to them. They work upon the same principle as the injector, but need no overflow nozzle. Little or no suction lift is desirable here, also, for the prompt starting and action.

110. How are the donkey, fire, ash-ejector, fresh water and sanitary pumps arranged?

In ships of small and medium size frequently only the

donkey is an independent steam pump, fulfilling most of t offices alternately through manifold valve connections. T donkey may also pump bilge or feed the boilers.

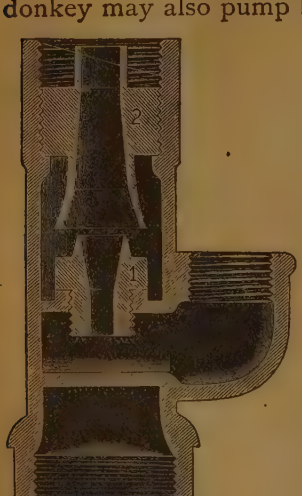


FIG. 141.—Section of a Type of Ejector. The steam jet emerges at lower pipe (1), carrying the water through the forcing or lifting tube (2).

The fire pump draws from t sea and discharges into a pi with hose connections and outl suitably placed between the upp decks in the different compartmer for fire extinguishing or washi decks. It is often used, also, to su ply water for the ash-ejector.

The fresh-water pump, eith steam or hand driven, draws fr the water tanks and delivers the galley, pantries and livi rooms.

The sanitary pump draws fr the tanks, or sea, and delivers to pressure tank on the highest de from which the closet, bath-roo etc., are supplied.

RULE IV, 1.—All steamers navigating oceans are required to be provided with fire buc and axes, as follows:

Gross Tons	Buckets	Axes
All steamers not over 10 tons	2	1
All steamers over 10 tons and not over 50 tons	4	1
All steamers over 50 tons and not over 200 tons	8	2
All steamers over 200 tons and not over 500 tons	16	4
All steamers over 500 tons and not over 1,000 tons	20	6
All steamers over 1,000 tons	25	8

Fire buckets shall be of a capacity of not less than 3 gallons each, but where buckets alr installed are of a capacity of less then 3 gallons each, they may continue to be used, and buckets of the standard size shall be added to provide the total capacity required.

Not more than six of the buckets required by this table shall be carried on the upper or deck.

Fire buckets shall, when practicable, be constantly filled with water, and in such pos on board as shall be most convenient for extinguishment of fire. (Secs. 4426, 4483, R. S.

Evaporating and Distilling Apparatus.—A distilling plant consists of an evaporator for evaporating brine or polluted water, a distiller for condensing the output of evaporator, a filter tank and the necessary pumps, *i.e.*, an evaporator feed pump, brine pump and a pump for circulating the condensing water through the distiller.

411. What are the functions and construction of the evaporator and distiller?

The evaporator evaporates salt water into steam, which is then condensed in the distiller or condenser to fresh water. It can then be used for drinking, boiler feeding and other purposes for which salt water could not be used.

The reason for fitting evaporators in ships is because of the loss

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RULE IV, 2.—All axes shall be located so as to be readily found in time of need, shall not be used for general purposes, and shall be kept in good condition. (Secs. 4426, 4483, R. S.)

RULE IV, 3.—All hay, straw, or other inflammable material carried on the open deck of any steamer carrying passengers shall be covered with a tarpaulin.

All baled cotton shall be securely bound and covered with bagging on at least three-fourths of its surface, including both ends of the bale. No bales of imported or domestic hemp shall be received on any vessel carrying passengers unless the same are properly compressed, bound with rope, wire, or metallic bands, and covered on ends or sides, according to the several methods now practiced in foreign and domestic trade. (Sec. 4472, R. S.)

RULE IV, 4.—The main pipes and their branches, on steamers carrying passengers or freight, to convey steam from the boilers to the hold and separate compartments of the same shall be not less than 1½ inches in diameter. Steam pipes of not less than three-fourths of an inch in diameter shall be led to all lamp lockers, oil rooms, and like compartments, which lamp lockers, oil rooms and compartments, in all classes of vessels, shall be wholly and tightly lined with metal. All branch pipes leading into the several compartments of the hold of the vessel shall be supplied with valves, the handles distinctly marked to indicate the compartment or parts of the vessel to which they lead.

RULE IV, 9.—Any steamer having on board an independent steam pump and an auxiliary boiler suitably arranged and of sufficient strength and capacity for testing the boilers thereof; or if one of the hand fire pumps be suitably arranged and of sufficient strength and capacity for testing the boilers; or if the "doctor," so called, when arranged permanently for testing the boilers, is, in the judgment of the inspectors, suitable for the purposes intended, may be considered as having complied with the law requiring a pump for testing boilers. (Sec. 4471, R. S.)

RULE IV, 10.—Any steamer of 50 gross tons or under, required to have a double-acting steam fire pump, and having in use on board a "doctor," so called, may be considered as having a lawful equivalent for such a pump when such "doctor" has pipes attached to it leading to the upper and between decks, such pipes being provided with hose and valves, according to law; but the pipes and hose shall in no case be less than 1½ inches in internal diameter. The pumps for supplying the boilers shall in no case be considered as an equivalent for the double acting steam fire pump, on steamers above 50 gross tons. Every steamer exceeding 150 gross tons and not otherwise provided for shall be provided with one good double-acting fire pump to be worked by hand: *Provided*, That when a steam pump is equipped to work by hand the same shall be accepted as a hand fire pump. Each chamber shall be of sufficient capacity and the stroke so regulated, that not less than 100 cubic inches of water shall be displaced by each stroke of the piston. Two smaller pumps may be allowed to take the place of the one pump of 100 cubic inches capacity provided for in this section when their combined capacity equals

of fresh water by leakage. This fact requires that an additiona supply of feed water be obtained either by carrying a supply i tanks or gaining it in the evaporator. In modern installation a certain amount of th product of the evapora tors is aerated and use for culinary purposes.

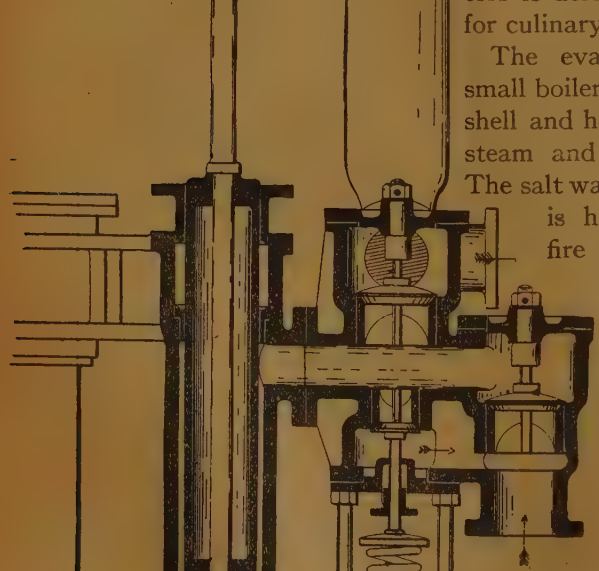


FIG. 142—Section of a combined feed and bilge pump.

The evaporator is small boiler, consisting o shell and heads and wit steam and water space The salt water it contain is heated, not b fire gases, but b steam fro the boiler o one of the mai engine receiv ers. Thi water circu lates throug an interna system of pi coils, until co densed and drawn on the condenser.

The steam thus gene ated, if of fairly hig

RULE IV, 10.—*Continued.*

or exceeds 100 cubic inches. Each pump shall be placed in the most suitable part of the ve for efficient service, having suitable, well fitted hose to such pump long enough to reach to parts of the vessel. Pumps may be connected to a pipe line having sufficient number of out so arranged that any part of the vessel can be reached with water by means of a single 50 f length of hose from at least one of said outlets, pumps to be kept at all times in perfect order, w brakes, and hose coupled on ready for immediate use: *Provided*, That on freight steamers hav hulls constructed entirely of metal only such hose shall be required as may be necessary reach all cabins or super-structures, such hose to be coupled on at all times. (Sec. 4471, R.

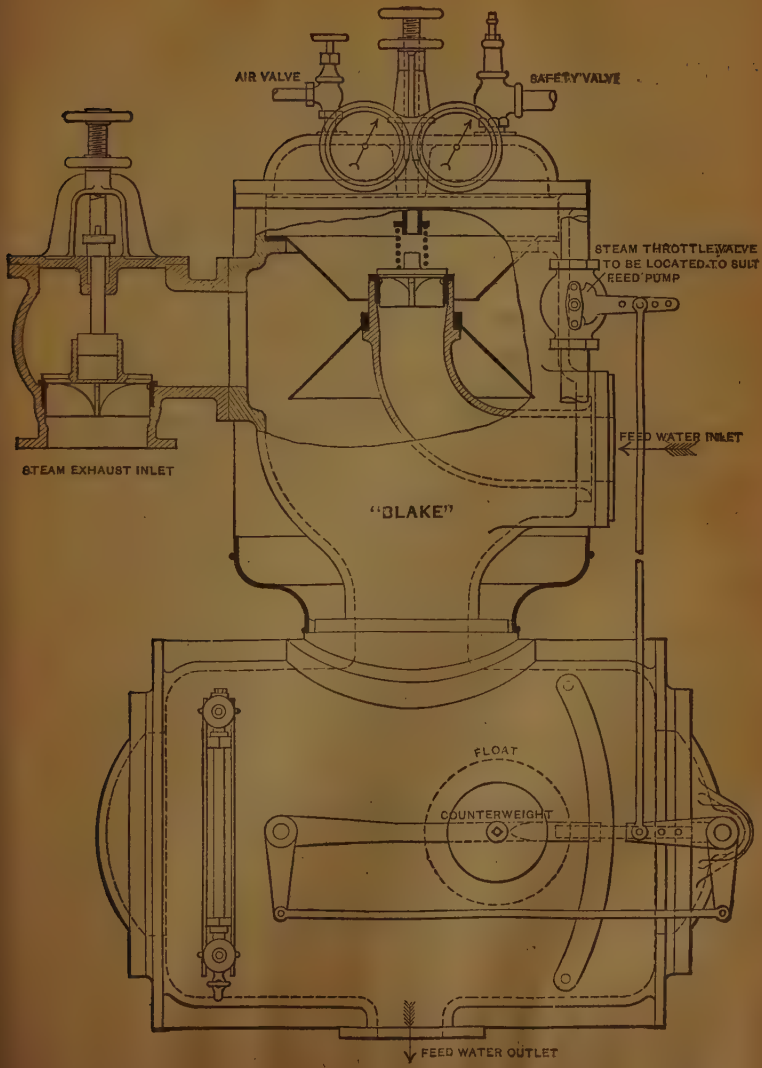


FIG 143.—Section of a Type of Exhaust Steam Feed Heater, with Parts Designated.

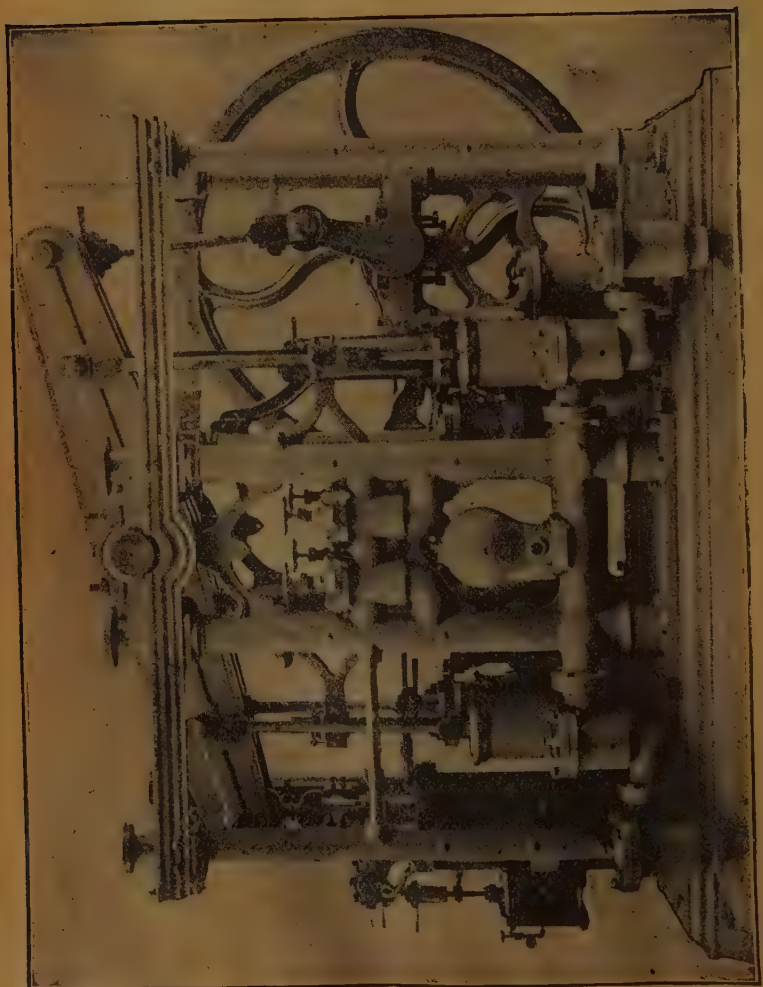


Fig. 141.—Double-acting Independent Force Pump, commonly called the "Doctor." (See Section 404.)

pressure, may be employed in a second evaporator, thus securing a double effect. For boiler feeding all the condensed water and low pressure steam is led to the condenser, from which point the air pump delivers it, in form of water, to the hot well.

If the evaporator steam is to be used for production of drinking water it is led first to a special nozzle system called the aerator, where air is mingled with it to make the water drinkable. From the aerator it passes through tinned condenser coils, cooled by circulation of sea water, into a filter, or storage tank, ready for use.

Through the evaporation of the salt water a very strong deposit of salt is thrown down upon the heating coils, which must be removed frequently for the efficiency of the heat transmission. Some constructions provide for an easy removal of the whole coil system, while others crack the scale off by sudden contraction of the hot coils by cold water and removal of the scale from the bottom through man and hand holes.

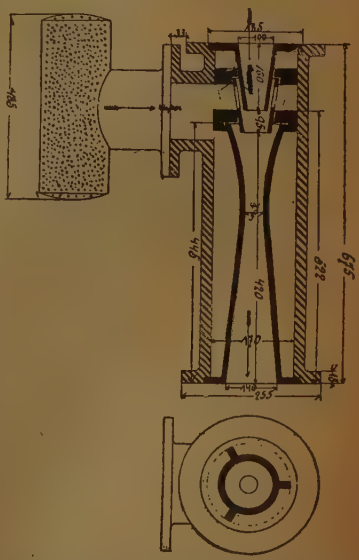


FIG. 144*a*.—A Steam Jet Bilge Ejector. The strainer through which the bilge water is drawn is shown at the upper left hand side of the diagram.

Evaporators are fitted in the same manner as boilers, with steam gauge, safety valve, stop valve, water gauge, feed check, bottom blow valve and salinometer cock.

The Plant in Operation.—The steam from the boilers (at a pressure which should not exceed 30 pounds per square inch) enters the top of the manifold of the evaporator, passes through the tubes, thereby being condensed, and is drained off through a

FIGS. 144b and 144c.—Reilly submerged type evaporator in open and closed positions. *In construction*, the shell is of cast iron, steel, copper or composition, depending upon the requirements. In all types the arrangement of coils and internal parts is identical. Standard shells are either of close grained grey cast iron or open hearth boiler and flange steel; doors and frames to correspond. The manifolds to which the coils are attached are of composition or cast iron; coils are of seamless drawn brass tubing, tinned or plain, rolled to shape without filing, in order to secure a uniform thickness of metal throughout. Coil ends are equipped with quick detachable flanged joints, free from brazing, making a metal to metal cone faced bolted joint. Baffles are arranged so as to increase circulation and prevent priming. The manifolds are securely bolted to the door, the coils being bolted to the steam and drain manifolds, thus permitting the entire nest of coils to be removed upon releasing the door. The weight of the door is taken off the studs by means of a jack roller. The door is guided by means of a slotted standard from the upper manifold, engaging with a fixed "T" track attached to the interior of the shell. The weight of the coils and manifolds is carried by composition rollers inside the evaporator. Zinc plates are used in steel shell evaporators, and are conveniently arranged for replacement.

steam trap, thence back to the boiler, carrying with it such heat as may remain.

The salt or polluted water surrounds the tubes and should not be carried at a height that would more than barely cover the top row of tubes; it is vaporized by the passage of the live steam through the tubes and should not be allowed to reach a pressure

FIG. 144*d*.—Coils and manifolds of Reilly multi-coil evaporator showing general arrangement.

in shell of over 10 pounds per square inch. The vapor passes over to the distiller, where it is condensed; the resultant water flows to the filter tank, from whence it is pumped or drained to storage tanks.

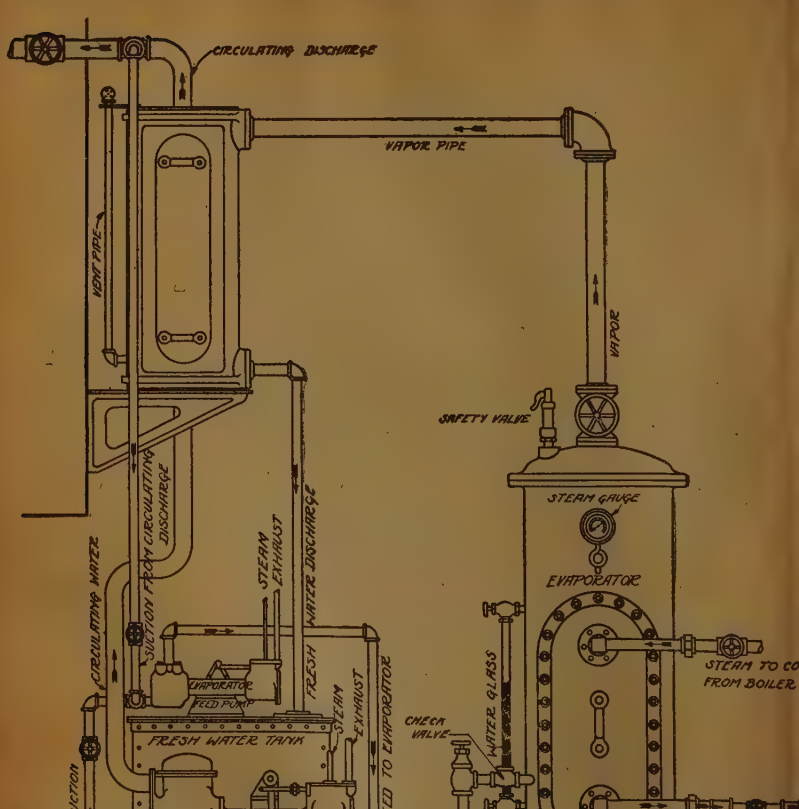


FIG. 144c.—Marine installation of Reilly multi-coil evaporator and distiller plant for feed mak up and drinking water. ***It consists of*** evaporator, distiller, aerating filter, circulatin pump, feed pump, trap and storage tank. These units may be located wherever desire except that the distiller should be placed as high above the evaporator as possible. Th steam for evaporator coils should be taken direct from boiler or auxiliary steam main, an the drain should be led to the trap, which discharges into hot well or filter box. The vapo connection on shell of evaporator should be valved, and led either to feed water heater, *l.* receiver, or to main engine condenser; the relative efficiency of the three methods dependin upon local conditions. A branch from the vapor pipe should be led to a special distiller fo drinking and culinary purposes. The condensed vapor from the coils of the distiller runs b gravity to the aerating filter, and thence to the fresh water tanks. The circulating pum and feed pump may be located wherever is most convenient; but when possible, locate th

The distiller circulating pump forces cold water into the bottom of the distiller, around the steam coils and overboard. As this water in its passage through the distiller becomes warm it is economical to use part of it for evaporator feed.

To Blow Off Brine from the Evaporator.—When a saturation of $\frac{5}{32}$ has been reached, with the feed pump running to keep the water at its normal level, start the brine pump and remove the brine, or shut off the boiler steam supply, and keeping the water

FIG. 144*f*.—***Davidson*** (Baird patent) evaporator type D. The rated capacity is based on an allowance of heating surface which is greatly excessive when tubes are clean, but this allowance is made so that the evaporator will give its full rated capacity even when tubes are scaled and not fully effective. With clean tubes the capacity given can be greatly exceeded. The shells are made of boiler plate, with dished steel heads both ends; the tubes are of steel or brass (as desired), expanded in sheet steel tube heads, and can be entirely removed by breaking one joint. The steam chest and tubes are tested to 250 pounds pressure and the shell to 50 pounds pressure per square inch. The following fittings are provided: Spring pop safety valve for shell, water gauge with fittings, steam gauge for coils, combined steam and vacuum gauge for shell, steam trap for drain from tubes, feed, blow, and drain valves, and salinometer pot complete with thermometer and hydrometer.

FIG. 144*e*.—*Text continued.*

evaporator feed pump close to evaporator, so that the engineer may conveniently time this pump according to the water level in evaporator gauge glass. The suction to evaporator feed pump may be taken either from the circulating pump discharge or direct from the sea. The evaporator feed pump discharge may be led directly into the evaporator, or if preferred may be first passed through a small feed water heater, taking its steam supply from the exhaust of the pump. When fitting up the feed pump, provide a branch from its discharge pipe to permit ready connection to steam manifold of evaporator for testing purposes when door is open. This avoids testing the coils with steam. The steam and exhaust to pumps may be arranged to suit conditions. The blow off from the evaporator should discharge overboard, with a suitable check valve at the ship's side. With this arrangement of piping, the evaporator will give the best results.

level at its proper height, wait until the machine ceases to operate, stop feed pump, then open up the brine cock and drain off the brine, then start feed pump and wash out evaporator; or when the evaporator feed pump is connected as shown, it is used to draw off the brine. In any case do not attempt to empty evaporator with steam pressure on the tubes, or a badly scaled evaporator will be the result.

"Making Up" Boiler Feed Water.—When it is desired to use all or part of the water evaporated for boiler feed, connection is made from the evaporator vapor pipe to the main condenser.

FIG. 144g.—Davidson (Baird patent) fresh water distiller. In connection with evaporators, distillers or condensers are employed to make suitable water for drinking, cooking, etc., the above make being manufactured in regular sizes with capacities from 125 to 5,000 gallons per 24 hours. Shells and heads of distiller are made of cast iron, or shells of copper with composition heads and flanges; tubes are of seamless drawn copper or brass, tinned inside and outside, secured in composition manifolds top and bottom, fitted with valves, by means of which any coil in the machine may be entirely shut off, so that in case of a leak in one coil the others may be used without stopping to remove the defective coil. With each distiller a galvanized iron filter tank and supply of animal charcoal is furnished. The water from distiller flows through the pipe in filter tank to the bottom, same and filters upward through charcoal and is drawn off at opening near top of tank.

It is good practice to evaporate the water thus under vacuum; when this is done the steam pressure in the tubes should be kept as low as possible, and care should be taken, when blowing off by the second method herein mentioned, to close the valve in the vapor pipe, to prevent breaking the vacuum in the condenser.

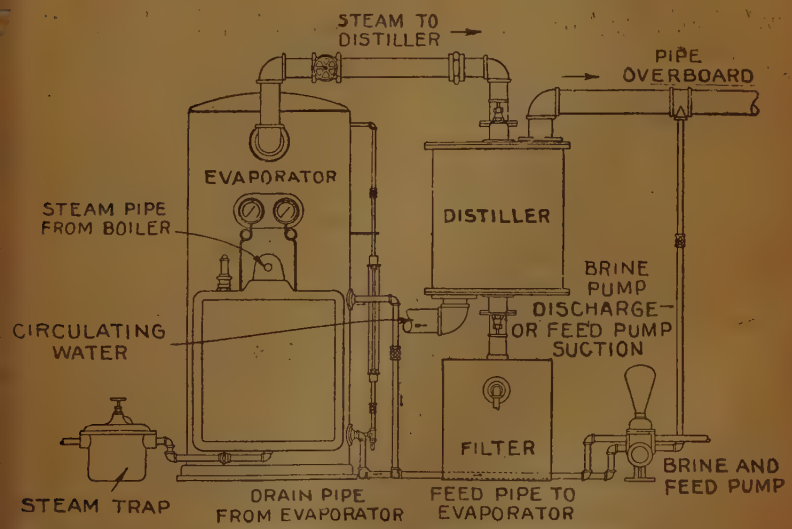
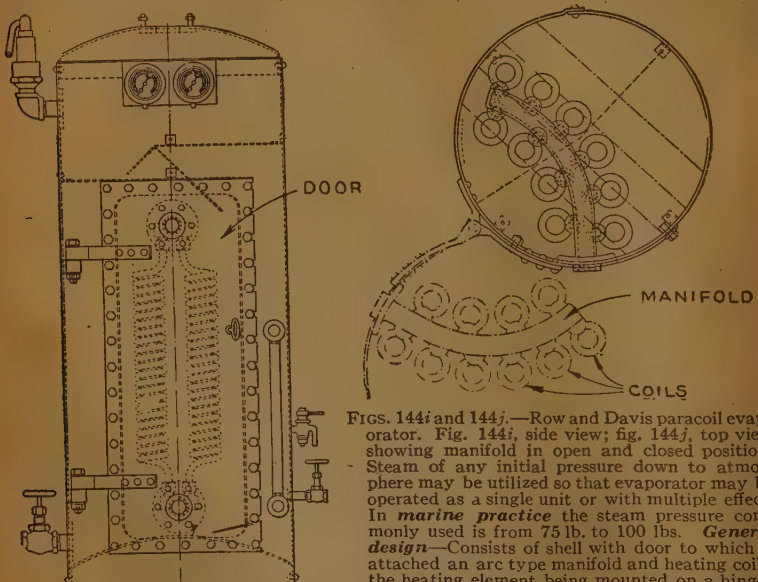


FIG. 144h.—Diagram of Davidson (Baird patent) evaporating and distilling apparatus showing manner of connecting up a plant to make drinking water; all parts are shown except circulating pump; one pump is used for both evaporator feed and brine.

On vessels making long voyages an evaporator is practically indispensable and even where the trip is of such duration that the supply may be replenished at different ports, the fact that all fresh water is not desirable for boilers, makes the use of an evaporator advisable in order to maintain the full efficiency of the boilers, prevent the formation of scale and the serious damage resulting therefrom.

Amount of "Make Up" Required.—The waste of feed water by overflow, blowing of whistle, leaks in the boilers, condensers, stuffing boxes, pipe joints and valves, varies greatly; it is more nearly in proportion to the quantity of feed water used than to the horse power.



FIGS. 144*i* and 144*j*.—Row and Davis paracoil evaporator. Fig. 144*i*, side view; fig. 144*j*, top view showing manifold in open and closed position. Steam of any initial pressure down to atmosphere may be utilized so that evaporator may be operated as a single unit or with multiple effect. In ***marine practice*** the steam pressure commonly used is from 75 lb. to 100 lbs. ***General design***—Consists of shell with door to which is attached an arc type manifold and heating coils, the heating element being mounted on a hinged door which enables same to be swung outside for convenient inspection, cleaning, or repair. A baffle in the top of vapor space is provided to prevent priming. ***Shell***—The cylindrical shell and its concave and convex heads are of open hearth boiler steel or cast iron as specified. The side of shell is provided with a large hinged door. ***Manifolds***—The top and bottom manifolds for steam inlet and condensation drain respectively are similar at top and bottom; are of cast iron or bronze and bolted to door. ***Coils***—These are of seamless drawn copper and are of a form that puts practically no strain on the joints. The helical form also provides for natural contraction and expansion under change in temperatures. This permits the scale to be removed by suddenly flooding the evaporator with cold water and blowing down at intervals, and to a great extent eliminates scaling by hand.

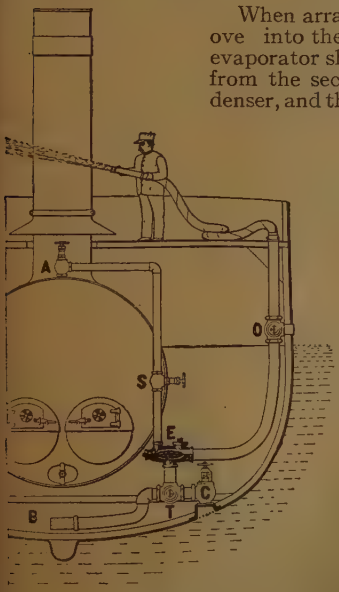
Usually a vessel filled with engines which give a horse power on, say, 1(pounds of feed water will waste less water per horse power than a vessel with engines requiring 40 pounds of feed water per horse power.

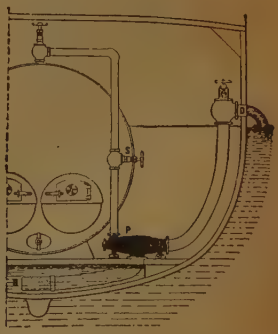
Experience shows that this loss will be about 2% of the feed water and th average consumption of water per capita for drinking, cooking and all ordinar

purposes, except bathing, is about 2½ gallons per day. The distilling apparatus is always made large enough to supply much more than the amount of water required, to allow for accidents, and also that the full supply may be obtained by running the apparatus a portion of the day.

Double Effect Evaporators.—In battleships and large passenger vessels where the economy of compounding is of sufficient value, the evaporators should be arranged in double effect.

When arranged thus, the vapor from No. 1 is carried ove into the tubes of No. 2. The drain from the first evaporator should be led to the hot well, and the drain from the second evaporator led to the fresh water condenser, and there cooled down to be used by the passengers





FIGS. 144*k* and 144*l*.—Koerting universal bilge syphons. Fig. 144*k* illustrates the use of syphon as a safety appliance on board ships; Fig. 144*l*, its use as an emergency bilge pump.

and crew. The generated steam from the second evaporater may either be used as a boiler make up, or led to the condenser or distiller. By compounding the evaporators, a saving of about 30 per cent. of the coal may be obtained.

Arrangement of Evaporator.—An evaporator may be arranged in various ways, depending upon the manner in which the vapor generated therein is to be utilized. The three principal methods of using the vapor are:

1. By discharging it direct into the condenser, there to mix with

the condensed steam, and be pumped into the boilers comparatively cold.

2. By discharging it into the low pressure valve casing, so that it does work upon the low pressure piston before being finally condensed with the main body of steam passing through the engine.

3. By utilizing it to heat the main feed water by means of a feed water heater.

FIG. 144*m*.—*Schutte and Koerting* vertical navy type evaporator with brass water chamber and steel vapor chamber; view showing coil removed from evaporator.

The comparative economy of these different arrangements is given below, and it will be seen that the most economical method of working an evaporator is to utilize the generated steam to heat the boiler feed water.

Evaporating Into the Condenser.—As it is usual to place a vapor or reducing valve between the evaporator and the con-

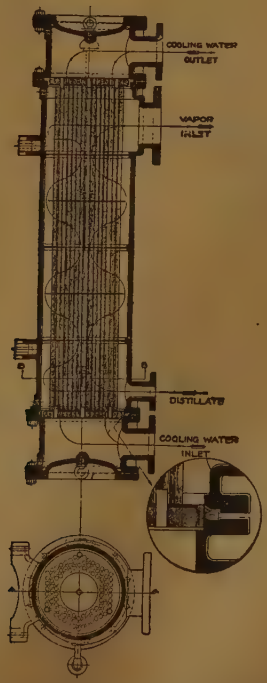


FIG. 144*n*.—***Schutte and Koerting*** distiller. The fresh water distiller is practically an ordinary surface condenser, which may be placed vertically or horizontally according to the particular requirements from time to time. The steam is admitted through a baffle plate to the outside of the tubes. The top portion of the tubes acts as a condenser for the vapor, while the lower portion of the tubes acts as a water cooler before it passes to the condensed water pump. The figure shows type Z, distiller which is of the straight tube construction designed to be placed in a vertical position, the circulating water flowing through the tubes and the steam passing around the outside of the tubes, a full cooling effect being obtained by means of special baffles shown in the illustration. The tubes are seamless drawn brass, tinned both inside and outside, shells and headers are cast iron. Special arrangement is provided which permits of free expansion and contraction of the tube bundle. The whole tube bundle can be removed for periodical cleaning if this should be found necessary. The distiller is provided with a vacuum breaker.

denser, it may be assumed that evaporation takes place at atmospheric pressure; and the temperature corresponding to this is 212° Fahr.

The water for feeding the evaporator being taken from the circulating discharge, its temperature may be taken at 80° Fahr.

To maintain the density at $\frac{2\frac{1}{2}}{32}$, two-fifths of the total amount of water admitted to the evaporator must be discharged into the bilge, and conse-

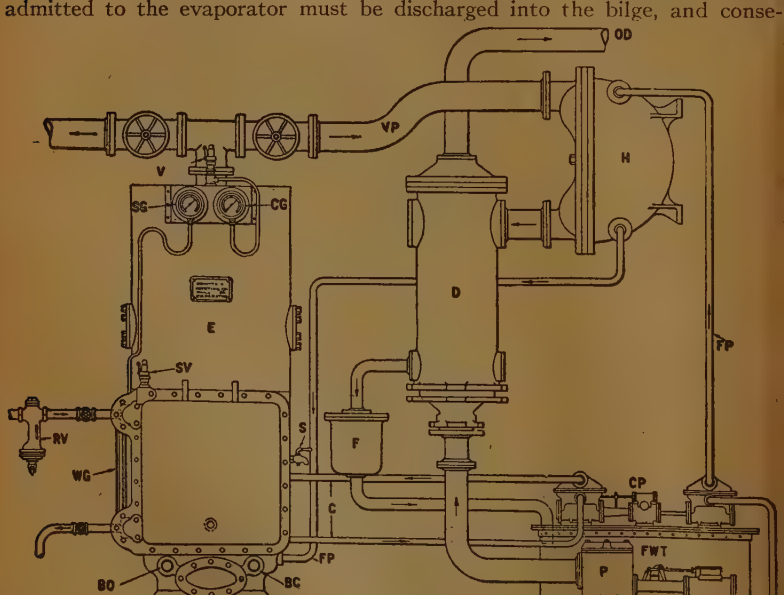


FIG. 144o.—***Schutte and Koerting*** arrangement of evaporating and distilling plants. ***The parts are:*** E, evaporator; D, distiller; F, filter; H, evaporator feed water heater; CP, evaporator circulating pump; FWT, fresh water tank; SS, sea suction; FP, feed pipe; C, circulating pipe; VP, vapor pipe; P, condensing pump; OD, overboard discharge; V low pressure safety valve; SG, steam gauge; CG, compound vacuum and pressure gauge; SV, high pressure safety valve; RV, reducing valve; WG, water gauge; S, salinometercock; BO, blow off; BC, brine cooler.

quently to produce 1 lb. of pure steam $1\frac{2}{3}$ lbs. of water must be admitted to the evaporator; of this, 1 lb. is evaporated and $\frac{2}{3}$ lb. discharged into the bilge as hot brine.

The total heat required to make 1 lb. of pure steam is the sum of the heat in the steam and that discharged in the hot brine.

Amount of heat, in thermal units, in 1 lb. of steam at 212° above 80°	1,099	thermal units.
Amount of heat in ⅔ lb. brine at 212° above 80°	⅔ of 132 = 88	"
Total heat required to make 1 lb. of pure steam, being the sum of the above	1,099 + 88 = 1,187	"

If it be assumed that 1 lb. of coal will evaporate 10 lbs. of water from and at 212° Fahr., that is, that 9,666 thermal units will be obtained from the combustion of 1 lb. of coal, it follows that the amount of pure steam generated by 1 lb. of coal with this arrangement is

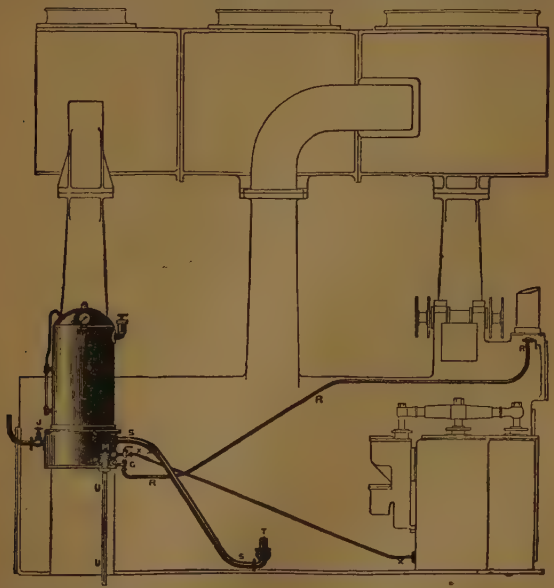
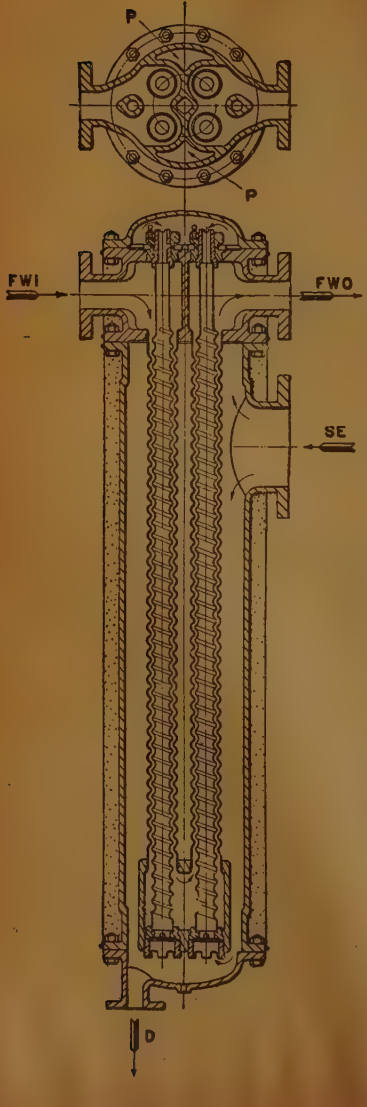


FIG. 144*p*.—***Evaporator*** arranged to ***evaporate into the condenser;*** simple but least economical. In this arrangement the steam generated in the evaporator is discharged into main condenser through the pipe S, and reducing valve T. The necessary feed water for the evaporator is taken from the circulating discharge by the pipe R, and enters the evaporator by the non-return valve G. The steam condensed within the coils flows by the pipe X, to the hot well. A pipe U, conducts the brine from the brining cock M, to the bilge. By placing the reducing valve T, low on the condenser, as shown, the steam from the evaporator is allowed to mingle with the feed water, and thus heat it to a slight extent. The amount of heat thus utilized is, however, necessarily small, as it is impossible to raise the temperature of the water above that corresponding to the vacuum in the condenser. With this arrangement, as the water flows into the evaporator by its own weight, it is necessary to place the apparatus as low as possible, so that there may be a considerable head of water.

$$\frac{9{,}666}{1{,}187} = 8.14 \text{ lbs.}$$



Consequently, to make 1 ton of fres water the amount of coal required is—

$$\frac{2{,}240}{8 \cdot 14} = 275 \text{ lbs.}$$

Evaporating Into Low Pres sure Valve Chest.—In this cas the steam from the evaporator i discharged into the low pressur valve casing, and does work upo the low pressure piston befor being condensed. There is there fore a saving over the previou arrangement, which may be cal culated as follows:

In an economical triple expansio engine 17 per cent. of the total heat i the steam is turned into work, conse quently if it is assumed that the powe developed in each cylinder is equa one-third of this (or 5·66 per cent.) i developed in the low pressure cylinde

Also, as 17 per cent. of the tota heat is utilized, 83 per cent. must be re

---

FIGS. 144*q* and 144*r*.—***Schutte and Koertin*** spiral corrugated feed water heater. ***I construction,*** the outer tubes are expande into the headers and the inner tubes the screwed into place; the outer joints mad tight by nuts which are locked securel Expansion and contraction of tubes, due t heating and cooling is taken up by th floating header, which is free to mov ***In operation,*** steam enters at SE, fil the entire shell, passes up through th ports P, shown on the plan view, fills th inside of the inner tubes and drains dow through the inner tubes then to the commo drain D, where all the condensed water pass off to the feed tank. The feed water ente at FWI, passes through the film formed b one half the tubes to the floating heade then through the other half of the tubes an out at FWO.

jected; the amount of heat entering the *l.p.* cylinder must therefore be 88.66 per cent. of the total heat. That is to say, out of the total heat entering the *l.p.* cylinder the amount utilized is

$$\frac{5.66\times100}{88.66}=6.38 \text{ per cent.}$$

Had this heat been used in the same manner as the rest of the heat passing through the engine, the amount utilized would have been 17 per cent. The amount regained in the *l.p.* cylinder is therefore

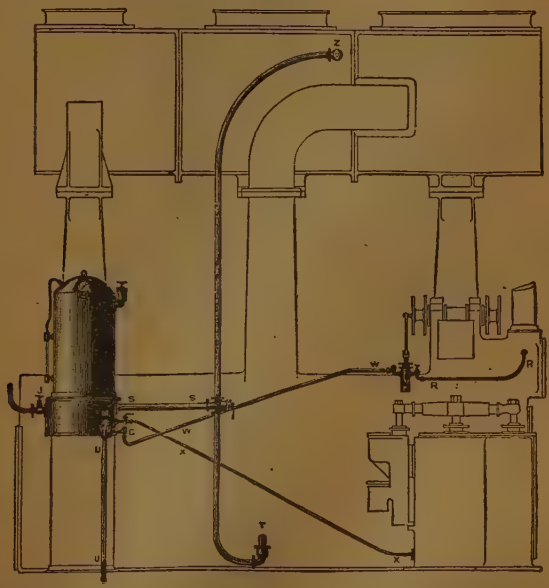


FIG. 144*s*.—***Evaporator*** arranged to evaporate into ***the low pressure steam chest.*** Here it is necessary to fit a small pump V, for the supply of water to the evaporator. This water is taken from the circulating discharge, as before, by the pipe R, and enters the evaporator by the pipe W, and non-return valve G. A two way cock Y, is placed in the steam pipe S, and it is thus possible to discharge the steam from the evaporator into the *l.p.* valve casing, or into the condenser at will. A non-return valve Z, should be placed on the *l.p.* valve casing. In ordinary cases with the engine working, the steam from the evaporator would be led into the *l.p.* valve casing; but when the evaporator is used in port the steam is discharged into the condenser, thus allowing any waste of water to be made up.

$$\frac{6.38\times100}{17}=37.5 \text{ per cent. or } \tfrac{3}{8}.$$

Now, let the pressure in the *l.p.* valve casing be 7 lbs. per square inch, the temperature corresponding to which is 233.1° Fahrenheit, and let the temperature of evaporator feed water be 80° as above, then

FIGS. 144*t* to 144*w*.—Schutte and Koerting grease extractor and feed water filter; view showing filter basket removed. Filtration is effected by means of terry linen which is wrapped around several oval cartridges comprising the filter basket. Bypass valves are so arranged that when filter basket is being removed for cleaning, the course of the feed water is directed to the boiler, without filtering. On the inlet and outlet to the filter body, suitable connections are arranged for fitting gauges, for the purpose of determining when filter should be cleaned. The terry linen can be regenerated, by boiling in a solution of soda and water. The effective area through the filter basket is 105 times the area of the pipe line, thus minimizing the number of times the basket need be removed for cleaning. Suitable connection is also made at base of filter body for blow off. Extractor is placed in the feed line, between the feed pumps and heater, or boiler. ***In operation,*** water from the feed pumps enters through valves on extractor to the filter body and travels through the filtering basket to the heater or boiler. With the increasing accumulation of foreign matter on the filtering material, the resistance indicated by the pressure gauges connected to the inlet and outlet of the filter body will increase. When the difference amounts to 20 lbs., the filter should be cleaned. An automatic water relief valve should be provided in order to prevent excessive pressure in the line between pump and extractor. The filter is put in operation by fully opening the inlet and outlet valves, while by closing the valves the water is bypassed.

Amount of heat in 1 lb. of steam at 233.1° above 80°..... } 1,104.5 **thermal units.**

Amount of heat in ⅔ lb. of brine at 233.1° above 80°..... } ⅔ of 153.1 = 102.1 "

Total heat required to make 1 lb. of pure steam, being the sum of above..... } 1,104.5 + 102.1 = 1,206.6 "

Amount regained in *l.p.* cylinder..... } ⅜ of 1,104.5 = 414.2 "

Net cost of making 1 lb. of pure steam is.. } 1,206.6—414.2 = 792.4 "

Amount of steam generated per lb. of coal. $\left.\begin{matrix}\\\\\end{matrix}\right\} \frac{9,666}{792.4} = 12.19$ lbs.

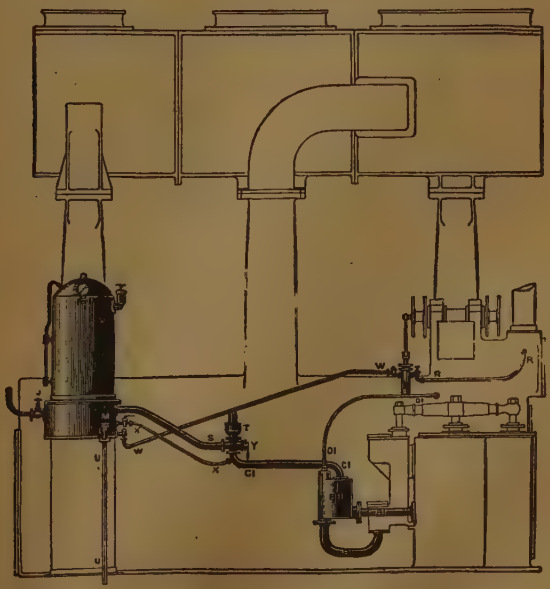


FIG. 145.—***Evaporator*** arranged to evaporate into ***feed water heater.*** The feed heater is shown at FH. The water from the hot well enters by the pipe A1, and after being heated flows by the pipe B1, to the main feed pump suction. A two way cock Y, is placed on the evaporator outlet pipe S, so that the steam from the evaporator may enter the condenser by the reducing valve T, or may be conducted by the pipe C1 to the feed heater. The drain from the coils may be led by the pipe X, into the pipe C1, at any point beyond the two way cock, as shown. D1 is a pipe for the escape of air and vapor from the feed heater, and is led into the hot well at any point above the usual water level. For the purpose of providing pure drinking water, part of the steam generated in the evaporator may be condensed in any fresh water condenser, and, being free from grease, it is very suitable for this purpose.

Consequently, to make 1 ton of fresh water, the amount of coal require with this arrangement is—

$$\frac{2,240}{12.19} = 183.7 \text{ lbs.}$$

Evaporating Into Feed Water Heater.—In this case the steam pressure in the evaporator is about 1 lb. above the atmosphere and as the steam is entirely condensed among the feed water, an is thus pumped into the boilers, the only actual expenditure o heat is that caused by brining.

Let the steam pressure in the evaporator be 1 lb., the tempera ture corresponding to which is 216.3° Fahr., and let the tem perature of evaporator feed water be 80° as before, then

Heat in ⅔ lb. of brine at 216.3° above 80°. } ⅔ of 136.3 = 90.0 thermal unit

This being the whole expenditure of heat, the amount of steam generate per pound of coal is

$$\frac{9,666}{90.9} = 106.3 \text{ lbs.}$$

Therefore, the amount of coal required to make 1 ton of pure water is

$$\frac{2,240}{106.3} = 21 \text{ lbs.}$$

412. What pumps are needed for the evaporator and distille service?

A pump is needed for feeding the evaporator with sea wate and for circulating the cooling water through the distiller.

NOTE—***Evaporators.*** The advantages of supplying marine boilers with pure water a great, and are so obvious as not to need specifying. The necessity of it was not, however, severely felt until voyages of considerable length had been made with ships whose boilers wo at pressures of 100 lbs. and upwards. The weight of water evaporated in boilers, whose wo ing pressure is 150 lbs., is much greater in proportion to the size than was the case with th working at 75 lbs.; and the evils arising from the deposit of scale are magnified with the hig pressure and consequent higher temperature. Again, the liability to put on scale is great inasmuch as the losses from leakages are greater with the higher pressures. Hence, the system of making up loss of water by a supply from the sea, although a very simple and rea one, was not by any means satisfactory, and did not remedy the evil, but rather magnified The Admiralty and some private ship owners tried to obviate it by providing a supply of fre water in the double bottoms, or in tanks specially fitted for the purpose. This, however, w only half a remedy, inasmuch as the fresh water generally obtainable contained large quantit of lime and other salts which gave a hard deposit difficult to remove. Moreover this fre water cost money, and was so much extra weight to carry which really added to its cost. Th recourse was had to the auxiliary or donkey boiler to obtain distilled water, which meant expenditure of coal and labour in cleaning out these boilers after they had become coat These small boilers very soon got so coated that they had to be stopped for a thorough cle out; and during the time they were at work there was always the risk of damaging them. spite of these difficulties it was found to be the most satisfactory way of obtaining an ex supply for the main boilers, and, consequently, improvement was made in this direction supplying a small boiler, whose heat is obtained from either the steam direct from the m boilers or from the exhaust from one or other of the cylinders.—*Seaton.*

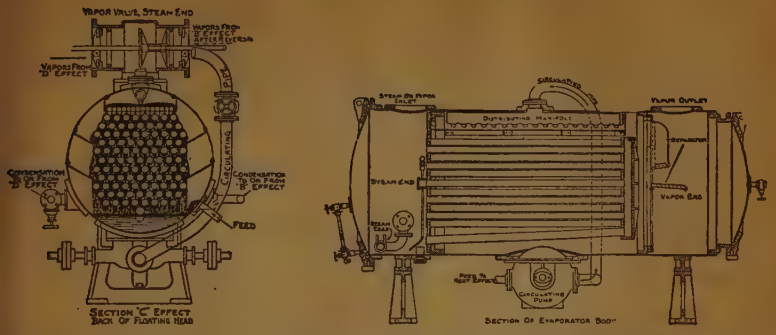


FIG. 145*a*.—Lillie evaporator, made by Wheeler Condenser Co. The operation of this evaporator differs from ordinary type in two respects: 1, evaporation from the sea water is from films caused by a mechanical showering of the sea water over the evaporating tubes; 2, the movement of the vapors or heat through the apparatus is periodically reversed. The former promotes the efficiency of the evaporating surface, and the latter, by a frequent changing of the temperatures through the *effects*, prevents incrustations to such a degree that the apparatus may be run for long periods without a material falling off in capacity. The evaporating tubes toward the steam end open through the tube plate partition, in which they are firmly expanded (without annealing). The other ends of the tubes open into a floating head or box, the front wall of which is a removable plate. The tubes are free to expand or contract independently of the shell of the effect. The tube plate, tubes and floating head may be taken from the body en masse, through the open head of the steam end after removing the bolts which hold the tube plate to the body flange. The tubes are staggered vertically, but not horizontally or diagonally, and may be cleaned by scaling irons when necessary. The heads of the effects swing on hinges, and are held closed by swing bolts. On the under side is a specially designed centrifugal circulating pump located midway between the ends of the body. Steam, or vapor from a hotter effect, enters the steam end, thence into the tubes, in which it is condensed by and causes evaporation from the sea water, which is circulated over the tubes by the circulating pump. The resulting vapors escape through a baffle plate into the "vapor end" and thence away from the effect at the top. A diaphragm which serves as a baffle separates the vapor end from the rest of the shell. At the top of this diaphragm is a hole through which the vapor enters, being deflected downward by a hood marked in the plate "Separator." Below this hood is a pan in which are placed inclined strips of copper to prevent any salt water which may be carried over into the pan splattering and thus becoming entrained. The concentration from the steam inside of the tubes flows either into the *steam end*, or into the *floating head*, depending upon the inclination given to the tubes by the motions of the ship. What flows into the floating head finds its way through the inclined pipe at the bottom into the steam end. From the steam end the condensation escapes through the steam trap to the steam end of the next coolest effect or to the surface condenser, with the exception that the one from the first, which is always the hottest effect, is taken away by itself for boiler feed, as it is more or less fouled by oil or odors contained in the steam used for evaporating. The circulation of the sea water over the tubes is a deluging shower, maintained by the centrifugal pump. The circulation is independent of ebullition, and there is no depth of sea water on the tubes, through which vapors must force their escape. The small quantity of sea water in the body is indicated. It consists of that in the body beneath the tubes plus that flowing over the tubes. ***Scaling by reversal.*** The change in temperature produced by this reversal is responsible for preventing the formation of scale in the effect by cracking off whatever scale may have been formed. If reversals be made systematically and with the frequency which experience with sea water may dictate, this evaporator may, with little trouble, be operated for many months without noticeably reducing its capacity. It is customary to reverse at intervals of about four hours when distilling sea water. The reversing operation is practically automatic, and in quadruple effects may be completed in five minutes or less.

One pump can, by suitable arrangement in the piping, fi
both of these functions, to the convenience of the engineer.

413. What difference is there between the steam cylinders o reciprocating and revolving auxiliaries?

The steam cylinders that transmit their power by recipro

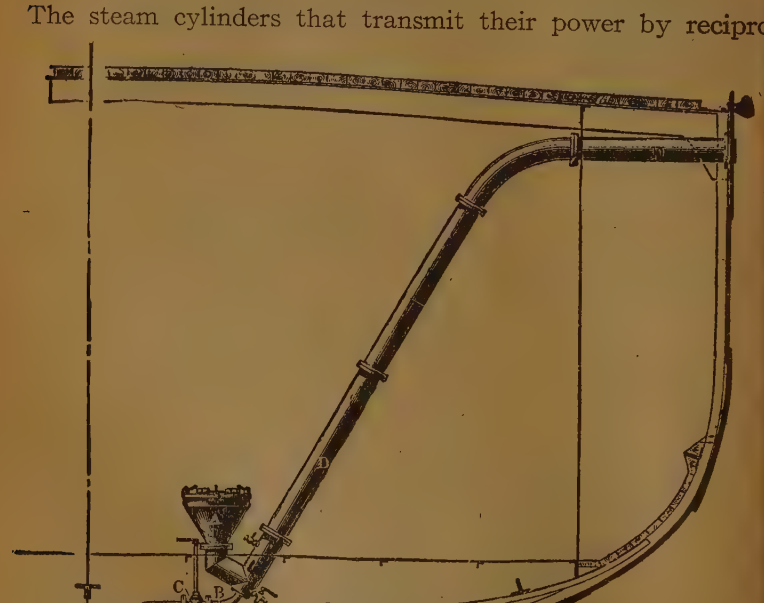
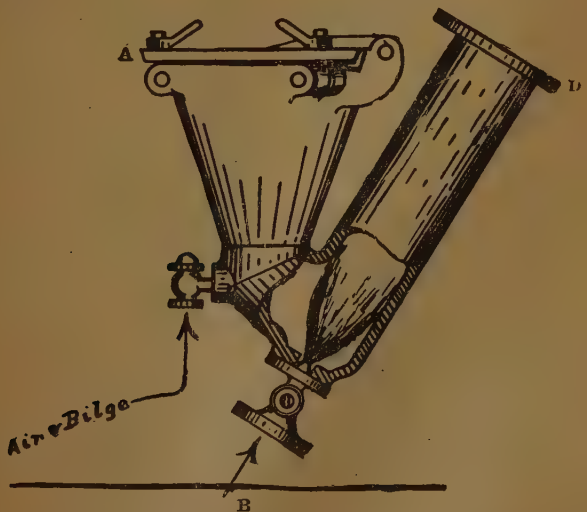


FIG. 146.—Ash Ejector. A, is the hopper into which the ashes are dumped; B, the water nozzle for admitting a jet of water from the pump; C, the water valve; D, the discharge pipe, leading over the side of the vessel.

cating motion only differ mainly in the valve gear from those transmitting their power by a combination of reciprocating and revolving motion.

The reciprocating motion allows no angular advance and no

lead or lap to the valves, giving thus full boiler pressure through the whole length of the stroke, with consequent lack of economy in the steam consumption. The valve motion is derived from the piston rod that rotates, or moves, a small auxiliary valve. A small movement of this valve allows steam to enter alternately through small steam ports, behind auxiliary pistons, which push the main valve at once to its maximum opening position.



IG. 147.—Details of Ash Ejector shown in Fig. 146. The letters correspond to the same parts as in that figure.

The valve gear of steam engines that transmit their power hrough a crank shaft is similar to that of the main engine, consisting of eccentrics, eccentric rods, valve stems and valves, vith angular advance, lead and laps. The transmitting gear of he cylinders, with reciprocating motion, consists of the piston od, directly connecting the two pistons, while in the other ype the piston rod connects through the cross-head and con-

necting rod to the crank-shaft, which drives the auxiliary worl ing machinery.

414. How are the steam cylinders of the independent aux iliaries and their gear constructed?

The auxiliary steam cylinders are arranged very similarly t

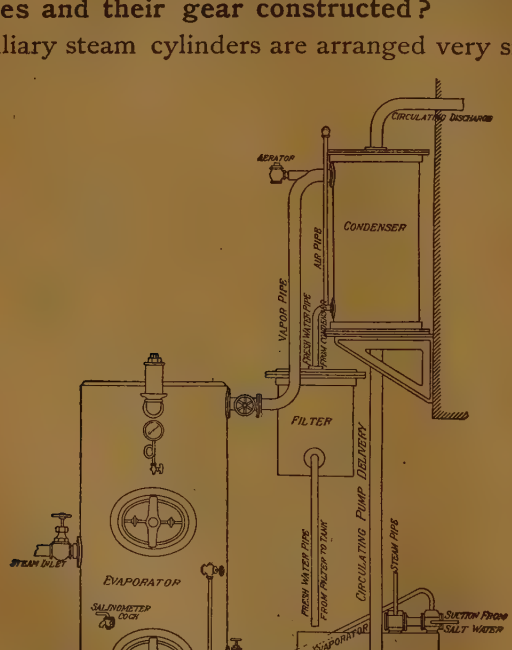
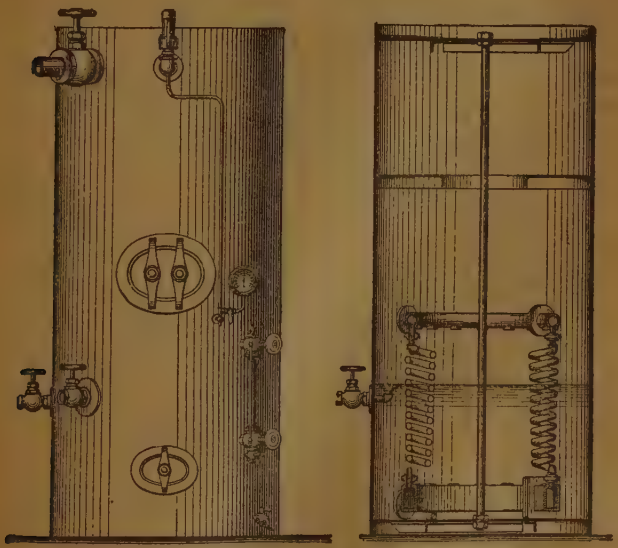


FIG. 148.—Evaporator and Distiller, with connections.

those of the main engine. The working barrel, bored for th working face of the piston, is fitted with heads, ports, valv chests and pipe nozzles, and is supported by columns or fram ing from the bed plate of the crank-shaft, the working pum cylinder or from parts of the ship. The cylinders and valv

hests are fitted with drain-cocks, to get rid of the condensed vater.

The cylinder castings are of cast iron, without liners, and he valves are plain slide or piston valves. The framing is ormed by cast-iron standards or wrought-iron columns. The uides are slipper guides on the standards, or columns. The



. 149.—Elevation and Section of a Type of Evaporator, such as is described in Section 411, and shown with connected parts in Fig. 148.

ed plates are of cast iron, and the bearings are often formed f Babbitt metal cast directly into the bearing or cap.

Everything is kept as simple as possible, with ample bearing rfaces, to insure the least possibility of breakdowns, adjust-ents or repairs.

The pistons, eccentrics and valves are of cast iron, while the ston rods, cross-heads, connecting rods and crank-shaft, as

well as the eccentric rods and valve stems, are usually of iro or steel.

The bearings in the moving parts are generally of bronze, in small parts only composition sleeves without adjustment.

415. What is the arrangement of the turnover engine?

The turnover engine is provided for the turning of the ma engine when in port and not under steam.

It is a small engine, connected by screw gear to a larg worm wheel on one of the shaft couplings, thus gaining a enormous leverage, so as to slowly turn the shaft, the pr peller and the main engine. In small main engines no stea turnover engine is fitted for this purpose, but a rachet lever f hand-power, or a rope sheave for connection to the donkey, other auxiliary engine, takes its place.

416. What is the arrangement of the ash-hoist?

Ash-hoists have to lift and discharge the ashes above t water line of the ship. Several types are in use. In son arrangements the ashes are lifted in buckets, to one of t upper decks, by reciprocating or rotating engines that pull wind the lifting ropes. This is rather laborious, as the ash must first be shovelled into the buckets, and then discharg overboard by hand.

The popular arrangement of ash-ejector avoids all handli by carrying the ashes in a jet of water through an inclin pipe above the waterline and overboard. The ashes a shovelled into a hopper, at the bottom of which they a picked up by a jet of water of high velocity, possessing suf cient momentum to elevate them in the inclined pipe.

417. What is the duty of the blowers?

The blowers are fitted for the purpose of improving t draft in the boilers, either by increasing the pressure under t grates or by decreasing the pressure in the uptake and sta

This forms the distinctive feature between forced draft and induced draft. With forced draft the blower forces air under the grates; with induced draft it sucks the air away from the uptake.

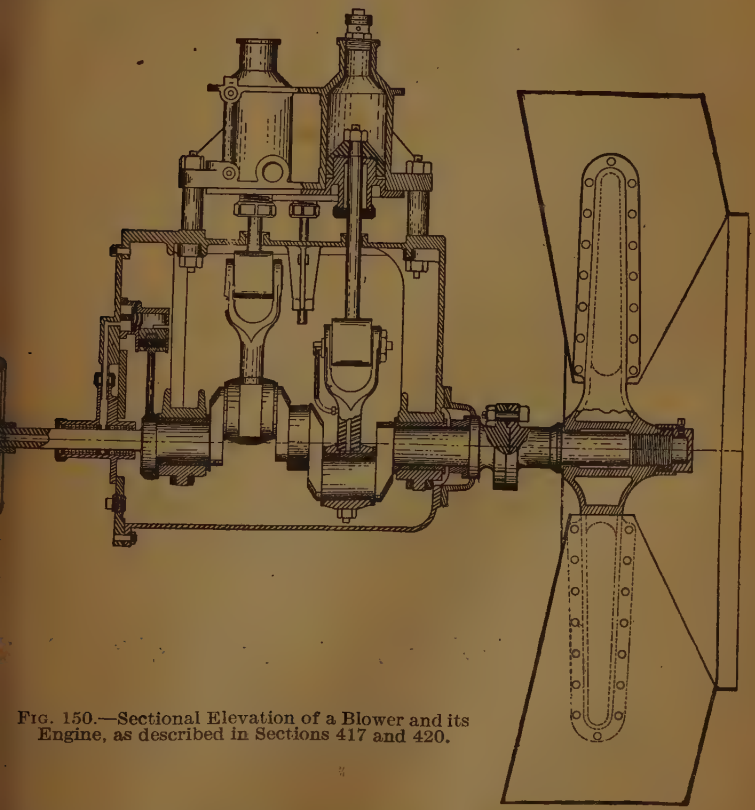


FIG. 150.—Sectional Elevation of a Blower and its Engine, as described in Sections 417 and 420.

8. What are the characteristics of forced draft?

Forced draft may be arranged in two ways: the blower may discharge either into a closed fire room or into a closed ash pit only. With the closed fire room an excess of pressure

must fill the whole room, necessitating air-locks and plac the firemen under the pressure, while with the closed ash only the furnace is closed, and communication with the room is the same as with natural draft.

A disadvantage of the closed ashpit system is the danger flames emerging from the fire doors when open, which ma it necessary to shut off the draft in firing. With the clo fire room no such danger is possible.

The closed fire room draft is, however, used practically o in the Navy, while the closed ashpit draft is extensively u in the merchant marine, and proves, with some precaution very useful means of increasing the steaming qualities of boilers.

419. What are the characteristics of the induced draft ?

The induced draft has the fan arranged in the upta drawing through the tubes and discharging into the smo stack. It lacks the disadvantage of the closed fire room, v the air-locks and the constant danger of blowing the flames of the open furnace mouth. It suffers, however, from severe heating of the fan and hard wear on the shaft beari working in contact with the hot uptake gases. Its best rangement is with air heaters, superheater or feed water heat that reduce the temperature of the gases as much as poss before they enter the fan.

420. How are the blowers and their ducts arranged constructed ?

The blowers are centrifugal fans, driven at a high numbe revolutions by a small steam engine, connected either dire or by belts.

Their duty is to supply a large volume of air at a low p ure.

The fans are plate discs carrying vanes, which must tran

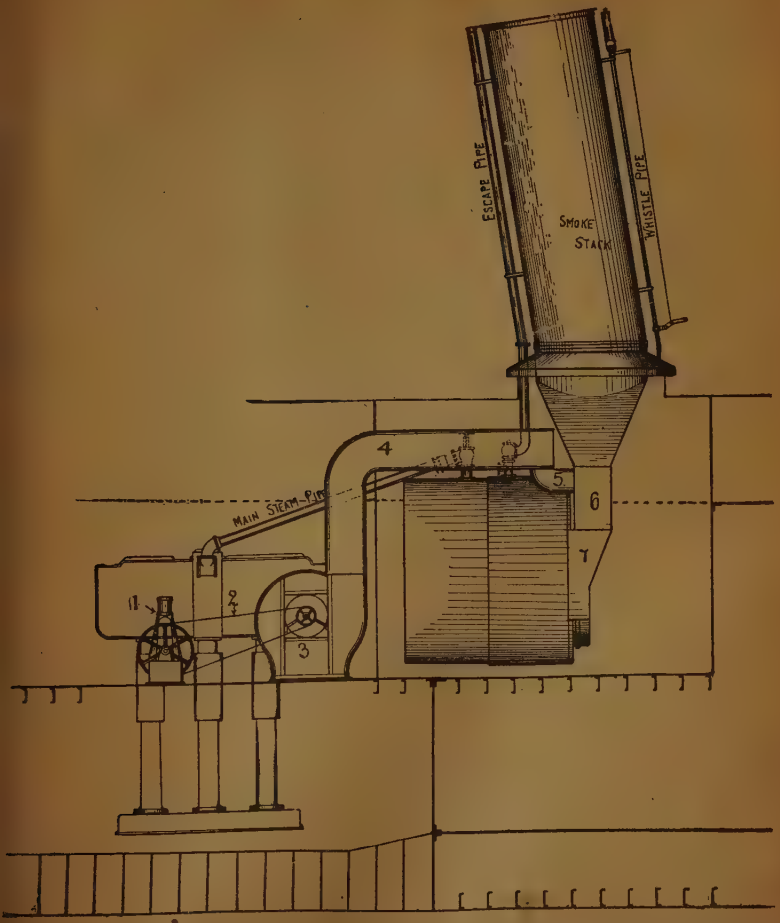


FIG. 151.—Diagram of the General Arrangements of the Blower and Duct of the Howden Draft. The numbered parts are: The blower engine (1); the blower engine belt (2); the blower (3); the single air duct (4); divided air duct, leading cold air into the nests of heating tubes (5); box containing nests of heating tubes (6); hot air duct with smoke-box in the centre (7). The nests of heating tube are shown in Fig. 152.

the velocity to the air. The air is drawn in at the centre, and discharged at the circumference into a casing that gathers and leads it to the ducts, or outlets.

The casings, fans and ducts are constructed of sheet iron or steel, connected and stiffened by angles.

The ventilators of the fire room furnish the supply of air for the boilers in natural, as well as forced, draft arrangements and should be large enough for an ample supply. Movable cowls, often worked by a gear from below, catch the force of the wind for a greater velocity of the supply.

Ventilators serve often as ducts for ash-hoisting, and are then fitted with pulleys for the lifting rope and doors for taking out the ash buckets. The closed fire room and induced draft system need very little air piping, while the closed ashpit system requires a lead to every boiler and furnace.

The Howden draft system, which is of the latter type, leads the air first to a nest of tubes in the uptake, on which it is heated to a high degree before passing into the ashpit. Some of the hot air is directed into the furnace above the fire to secure a better combustion.

421. What are the auxiliaries not directly connected with the propulsion of the ship?

(1.) The dynamo for the electric service.
(2.) The ice machine for refrigeration and ice making.
(3.) The steering engine for moving the rudder.
(4.) The winches for hoisting cargo.
(5.) The windlass for heaving the anchors.

422. How is the dynamo arranged and constructed?

The dynamo produces electric current of a certain tension by revolving coils of wire on the armature in the field of the electro magnets.

For marine purposes the compound wound dynamo, produ

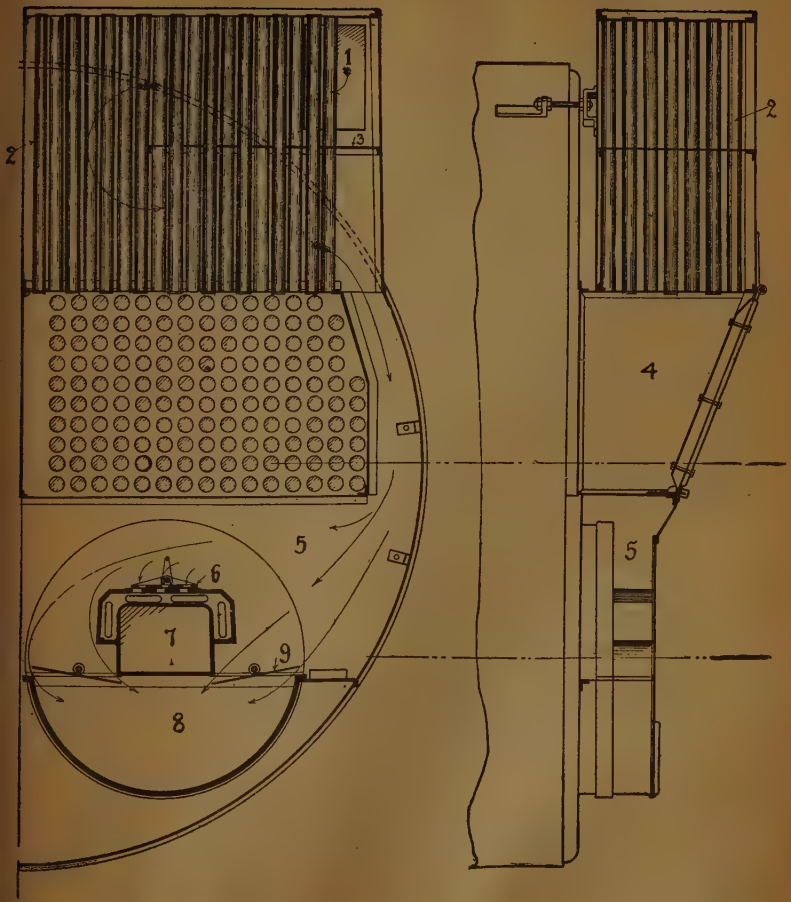


FIG. 152.—Air Heater of the Howden Draft. The numbered parts are: the cold air duct (1); nest of air heating tubes (2); baffle plate to direct the air current over the heating tubes (3); smoke-box (4); hot air box (5); sliding gate to admit or shut off hot air above the grates (6); the furnace (7); the ashpit (8); butterfly valves to shut off hot air from the ashpit (9).

ing a tension of about 110 volts, is most commonly used being usually connected directly to the crank-shaft of its steam engine. The armature is, preferably, independent of its shaft and keyed to it, so that it can be replaced by a spare one in case of burning out of the coils.

With the high speed of revolutions and the sensitiveness of the electric machinery to variations of speed, a close governing of the engine, careful lubrication, good alignment and balance is necessary upon strong foundations.

The heating of the armature should not exceed a certain rise of temperature above the atmosphere, and the brushes should slide, under gentle pressure, upon their commutator without sparking.

Different styles of dynamos are in use with two, four or six poles, requiring fewer revolutions with the larger number of poles.

Some forms have the field pieces shaped so as to enclose the whole dynamo, while others have it open. The dynamo is generally placed in the engine room under the direct supervision of the engineer. It should be a fair distance away from the instruments of magnetic observations to avoid disturbance in their indications.

423. How is the ice machine arranged and constructed?

The ice machine produces cold by abstracting heat from a transmitting fluid, through evaporation or expansion of the working fluid.

The working fluids largely used in marine practice are ammonia and common air, while the transmitting fluid is usually a strong salt solution or brine, which freezes considerably below the freezing point of water, and can thus be used to make ice.

The machine transmits the power from the steam engine to the compressor pump, in which the working fluid is liquified

or reduced to a smaller volume of higher pressure. The heat thereby generated is thrown off and carried away in a cooling condenser.

When ammonia is used the fluid passes directly to the cooling coils in the brine tank, where it expands and binds heat in latent form. When air is used it passes, first, into an expanding cylinder, doing work and assisting the steam cylinder in the compression; then, at a low temperature, into the coils of the brine tank, absorbing heat therefrom. The condenser has the cooling water generally supplied by a special reciprocating, circulating pump, driven by the same engine.

The ammonia system is very efficient, but needs great precaution in the installation, owing to the poisonous nature of the gas.

The stuffing-boxes, valve and pipe joints must be of extra strong and tight construction. Air is much more easily handled and obtained, but is not as efficient; besides it needs an extra expansion cylinder, with crank, connecting rod, piston rod, piston and complete valve gear.

The condensers are vessels fitted with coils or tubes, through which the cooling water circulates. They should be provided with efficient clothing and lugging, in order to concentrate the cooling effect as much as possible.

From the brine tank circulating pipes lead to the ice-boxes, or refrigerator rooms. They are generally arranged in coils, well distributed, to secure a uniform lowering of the temperature.

The ice machine is preferably installed near the engine room for convenience of attendance by the engineers.

424. How is the steam steering engine arranged and constructed?

The steam steering engine serves the purpose of turning the rudder of the ship more powerfully and rapidly than can be

done by hand. Its power is applied through rope, chain o gear transmission to a lever or sheave on the rudder stock But its operation is intermittent and is also peculiar, in that i

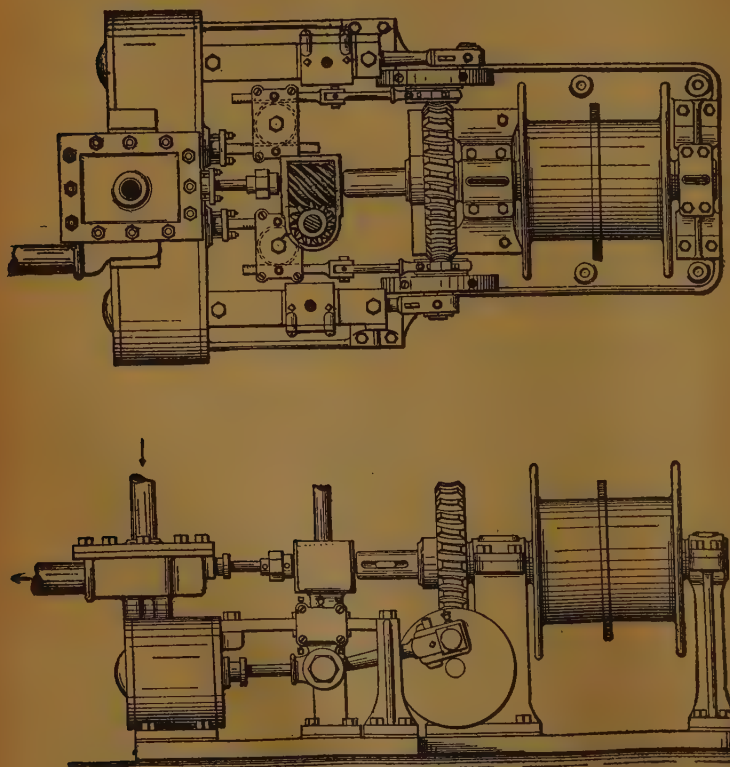


Fig. 153.—Plan and Side-elevation of a Steering Engine.

swings the rudder only through a part of the arc, less tha 90 degrees, while the engine makes several complete revol tions. It is made reversible by the change of steam ar

exhaust ports through a special valve, actuated by a hand-wheel on the bridge and closing automatically, when the desired position of the rudder is obtained.

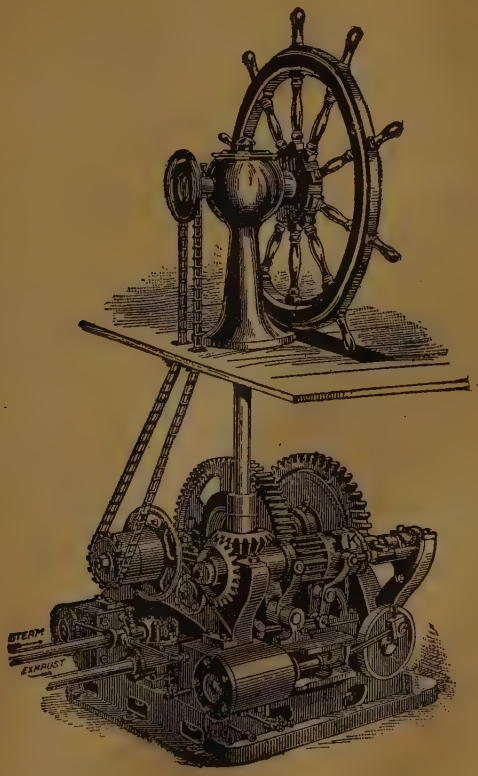


FIG. 154.—Steam Steering Engine shown connected to the pilot-house wheel. The operation of the engine valves is controlled by the chain and sprocket connection from the pilot-wheel shaft.

The steering gear consists of two complete engines, with regular valves, which, however, have no angular advance, lead or laps. The two cranks are set under 90 degrees, to

insure a positive starting in any position. The construction of the engines should be strong and durable, with large bearing surfaces, as the strains upon them may be quite severe in a sea-way.

The steam steerer is placed directly under the pilot house in the engine room or near the rudder stock. The transmitting gear needs attention in keeping it taut, and in providing that the position of the hand-wheel and its indicator corresponds to the position of the rudder.

425. What are the use and arrangement of the winches?

The winches are fitted for hoisting purposes. The power from twin engines is applied to chain or rope drums by helical spur or friction gearing. They are usually reversible by special valve or link gear, or, if not reversible, disconnect or loosen the friction gear of the hoisting drum for lowering of the load by its own weight.

The whole machinery should be strong and durable, as the attention received is often limited to the very smallest, while the service is severe. The winches are usually near the cargo hatches on the upper decks, in exposed positions, and require care to keep them in efficient working condition.

426. What are the use and arrangement of the windlass?

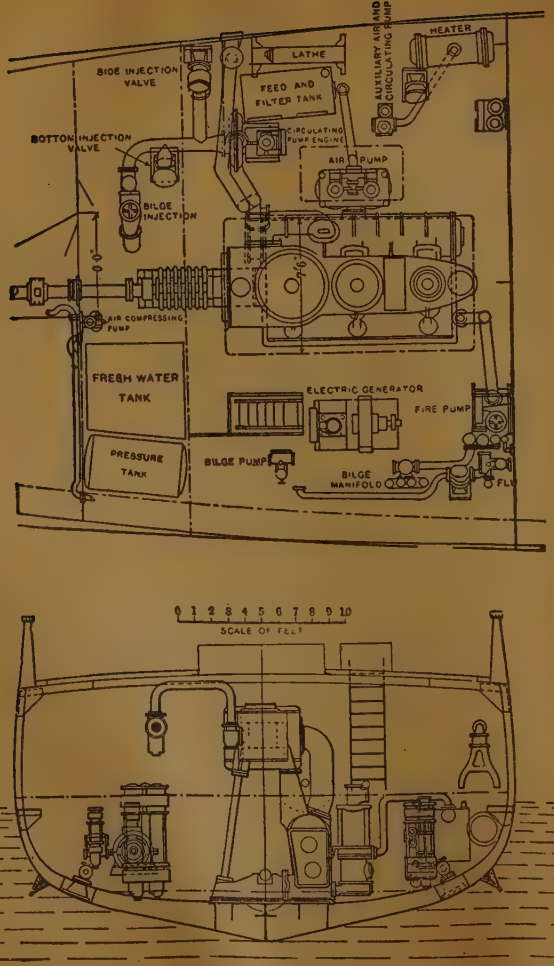
The windlass serves for heaving of the anchors and chains. The engines, generally double, with cranks at 90 degrees, drive the wildcats, over which the chains pass, through heavy bevel or helical gearing. The engines and working parts are very similar to the winches.

The windlass is near the bow, generally on the upper deck in an exposed position, that requires good care for its preservation in working condition.

PART SIX.

PIPING AND PIPE CONNECTIONS OF A MARINE ENGINE.

CHAPTER TWENTY—PIPING AND GENERAL OUTFIT.



General Arrangement of Machinery

Showing engine with built in condenser, also pump heater, tanks, piping, etc.

CHAPTER TWENTY.

PIPING AND GENERAL OUTFIT.

427. What is the function of the piping?

The piping conveys the working fluid to and from the main engine or the auxiliaries.

428. What classification is made in piping?

Piping may be distinguished by the material of which it is made, as:

(1.) Iron and steel piping.
(2.) Copper or brass piping.
(3.) Lead piping.

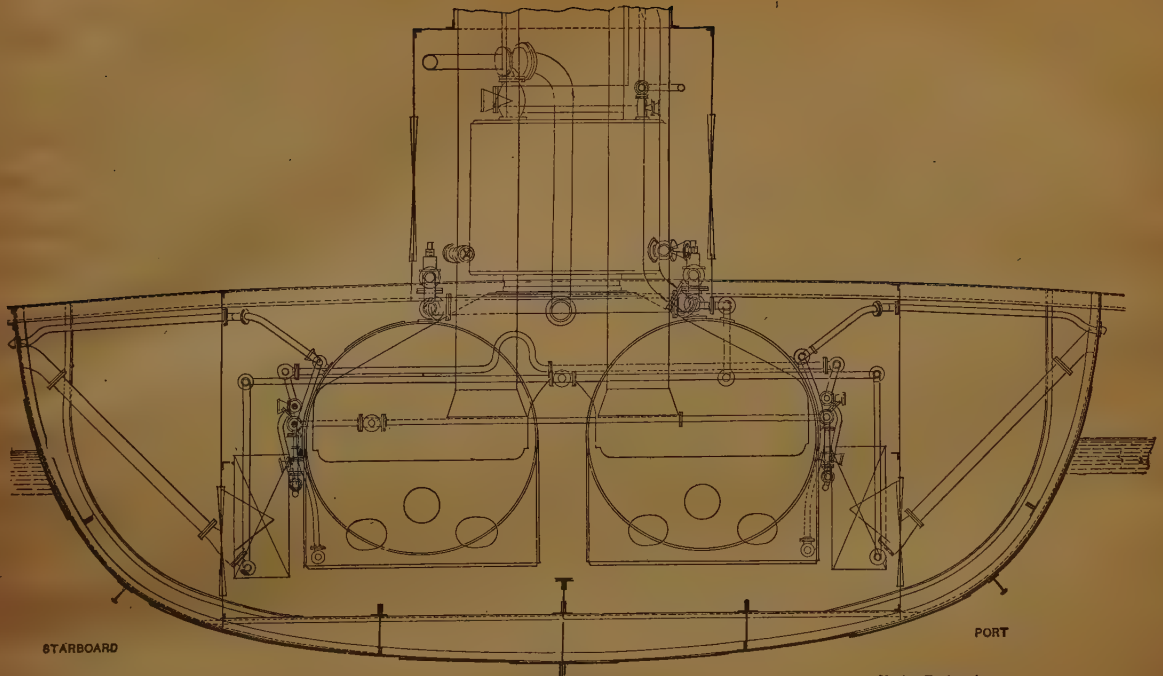
or by the working fluid it contains, as:

(1.) Steam piping.
(2.) Water piping.

429. What are the characteristics of iron and steel piping?

Iron and steel piping is chiefly valuable for strength and rigidity. It may be employed for high pressures and temperatures, but does not adapt itself readily to many bends. Its preference for straight lengths makes expansion arrangement necessary for steam pipes for high temperatures.

It is readily and strongly connected by screwed fittings in smaller sizes, and by screwed or riveted flanges in larger sizes. The methods of manufacturing it in lap welded or solid drawn tubes can produce thoroughly reliable and strong work, which may be used for high pressures and temperatures in preference to copper. It may also be used advantageously for steam and fresh water piping, where there is no danger of galvanic action, or rusting, under alternate exposure to air and



LOOKING AFT
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FIG. 155.—Transverse Section of the Twin-screw Sound Steamer "Hartford," showing boilers in position and piping

water. It should not be used for salt water piping, as it is not sufficiently durable and lasting Cast-iron pipes are sometimes employed, however, in heavy thickness, in ash-ejector tubes, where there is hard wear, or in receiver steam piping, also in bilge piping, where lead pipe would be easily damaged.

430. What are the characteristics of copper and brass piping?

Brass piping is used in small sizes only, while copper piping finds its largest application in steam and water leads.

Its principal advantage lies in the ease with which it may be shaped in bends and varying sections, owing to the natural ductility of the copper and the possibility of joining several sheets, or pieces, together by brazing. The necessary expansion can readily be obtained in bends, thus avoiding all sliding joints. The connections are made by flanges, soldered upon the pipes, which are expanded and beaded over into a recess in the face of the flange.

A serious drawback to its use in high-pressure and high-temperature pipes is a certain unreliability of the brazing joints and a loss of strength under high temperatures. Grave accidents have often occurred in large copper steam pipes, which have seriously shaken the faith of engineers. Methods have been devised of strengthening the piping by flat bands or coils of wire on the outside. Copper or brass pipes may be used with the greatest advantage as salt water leads, or where alternately exposed to water and air, such as fire, main and bilge piping, when not exposed to the action of bilge water in iron hulls.

The reason for avoiding its use in iron hulls is that copper and brass will set up galvanic action, destructive to steel and iron, in bilge or salt water, if connected and immersed with the iron or steel.

Brass piping is joined by screwed fittings or flanges, in the

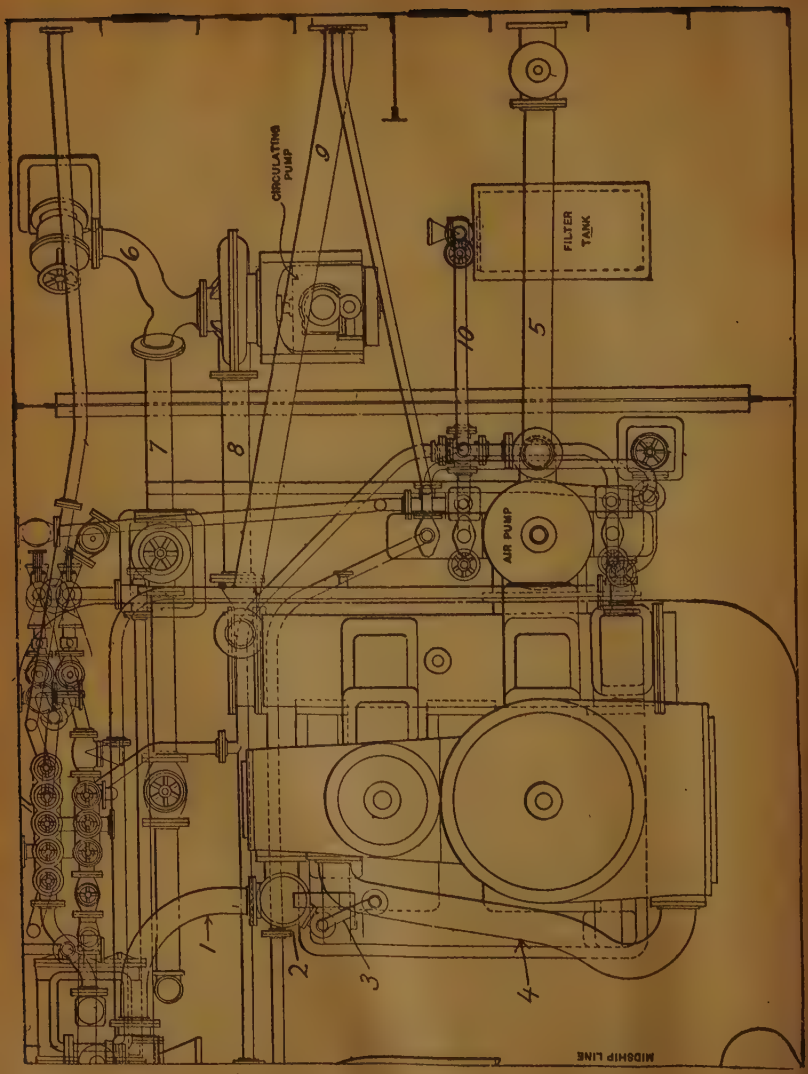


FIG. 156. (For description, see bottom of page 363.)

same manner as iron and steel piping, with which it shares a greater stiffness and rigidity and less adaptability to bending than copper.

431. What are the characteristics of lead piping?

Lead piping is characterized mainly by great ductility, absence of strength and rigidity and a low melting point. It is not suited for pressure pipes or those with temperatures above the normal atmosphere. Its indifference to iron and steel, as regards galvanic action, renders it a suitable material for bilge suction pipes.

432. What are the characteristics of steam piping?

The steam piping is exposed to the high pressures and temperatures of the contained steam, and should, therefore, be amply strong in its walls; should be of material that will not lose its strength materially upon heating, and should allow amply for longitudinal expansion, or contraction, due to great temperature differences.

433. What are the characteristics of water piping?

The water piping is exposed mostly to pressure, while temperature variations of any extent are generally absent, and rarely of much magnitude. Strength, rigidity and tightness are the chief requirements, which may be provided without difficulty.

434. What are the most important steam pipes?

(1.) Safety valve escape pipe.
(2.) Whistle pipe.
(3.) Main steam pipe and branches.
(4.) Receiver and exhaust pipes.
(5.) Auxiliary steam and exhaust pipes and branches.

FIG. 156. (Page 362.) —Piping and General Arrangement, Starboard Engine Room of the Twin-Screw Sound Steamer "Hartford." The numbered parts are: The main steam pipe (1); the throttle valve (2); the pass-over valve (3); the receiver pipe between the H. P. and L. P. cylinders (4); overflow and delivery from hot well (5); circulating pump suction pipe from sea valve (6); bilge suction pipe (7); delivery to condenser (8); outboard delivery (9); suction pipe of feed pump (10); manifolds for bilge pumping and various purposes (11).

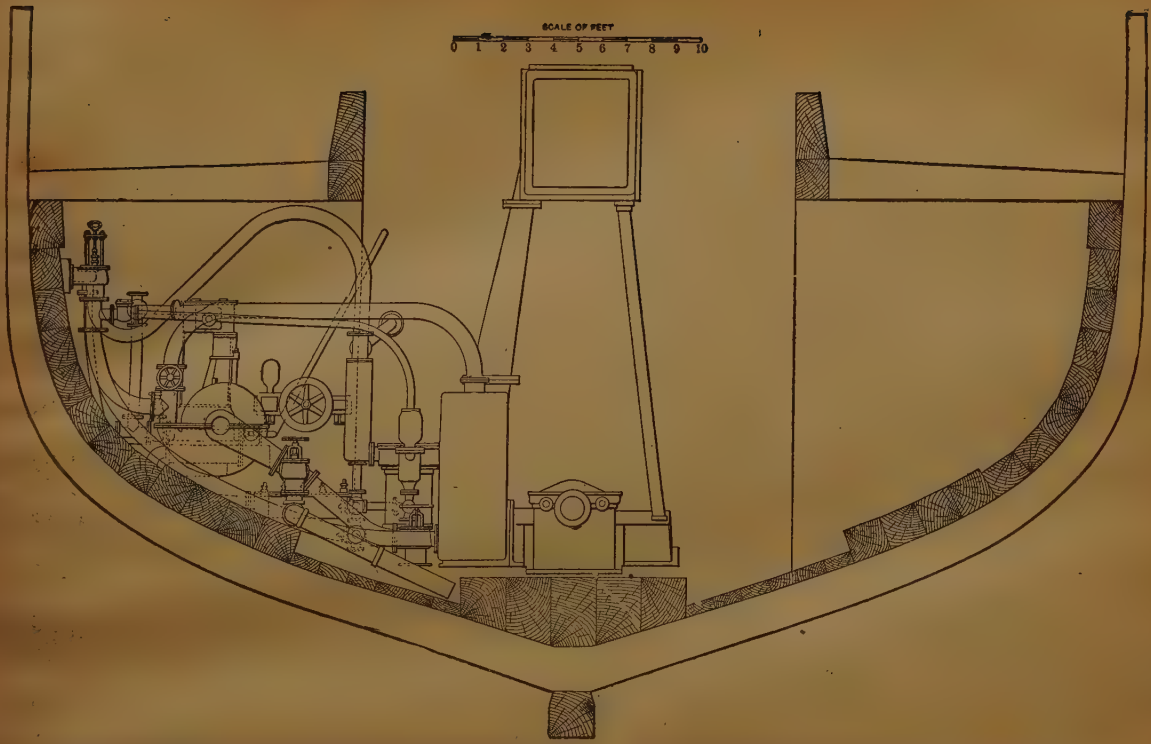


FIG. 157.—Transverse Section Through the Pacific Coast Steam Schooner "Santa Anna," showing general arrangement

435. How are the safety valve escape pipe and the whistle pipe arranged and constructed?

The escape pipe carries off the excess of steam blown off through the safety valve. To prevent injury it leads straight up into the air behind the smoke-stack and is stayed and held in place by it.

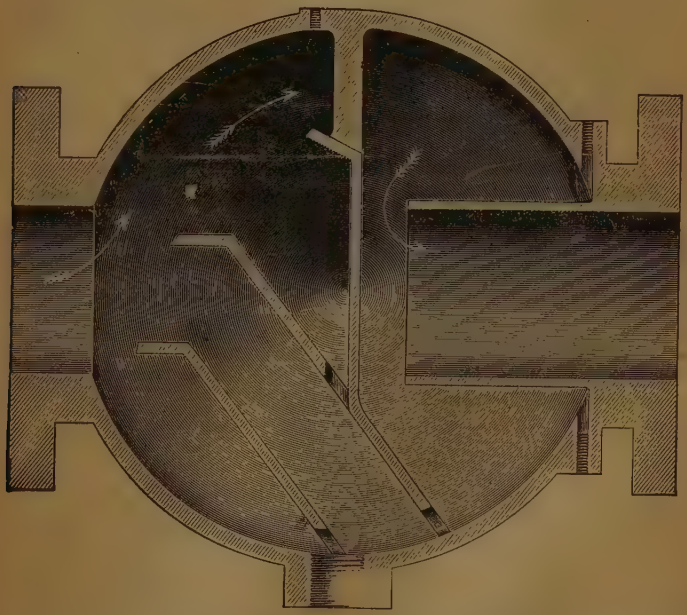


FIG. 138.—One Form of Steam Separator Fitted upon the Main Steam Pipe. (Section 436.)

It is generally of copper, being severely exposed to the corroding influence of air and moisture.

A flaring top is usually provided to reduce the roaring noise of the escaping steam, as much as possible, and the connections are made by flanges.

The whistle pipe is arranged on the forward side of the smoke-stack, conveniently for rope connection to the pilot

house, with as straight and vertical a lead as possible, to let all condensed water run back by gravity into the boiler and have fresh steam always ready to enter the whistle. It should be lagged sufficiently to reduce the condensation. Its material is generally copper, brass or iron. Being small in diameter, it is connected by flanges or screwed fittings.

436. How is the main steam pipe arranged and constructed?

The main steam pipe leads the steam from the boiler to the engine. On account of its great importance it should be arranged in the most careful manner. For the purpose of obtaining superior strength, solid drawn steam pipes are now preferred, for the very high pressures and temperatures, by some engineers, while copper is still the choice of others, particularly for lower pressures. Flanges of substantial character are employed for the connections.

In straight pipes, expansion joints, with composition sleeve and composition mountings, are provided, to prevent longitudinal compression or tension strains, under the expansion of the material at high temperatures. The expansion joints should have safety collars and bolts, in order to prevent a complete blowing-out of the sliding pipe from the joint. Another method avoids the troublesome packing of the joint by putting large bends or bellows into the pipe that will accommodate the expansion and contraction.

Great care should be taken to avoid all pockets in the pipe that could retain water, as sudden acceleration of this water under the new inrush of steam, upon opening of the stop-valve, might produce water hammer sufficiently powerful to break joints and wreck pipes. Careful draining of this and all

RULE II, 27.—The wearing surface of the male pipe in all slip joints made after June 30, 1908, for use in steam pipes shall be of copper or composition, and the said male pipe shall be of sufficient length and so adjusted as to prevent accidental withdrawal from the stuffing box. (Secs. 4405, 4418, R. S.)

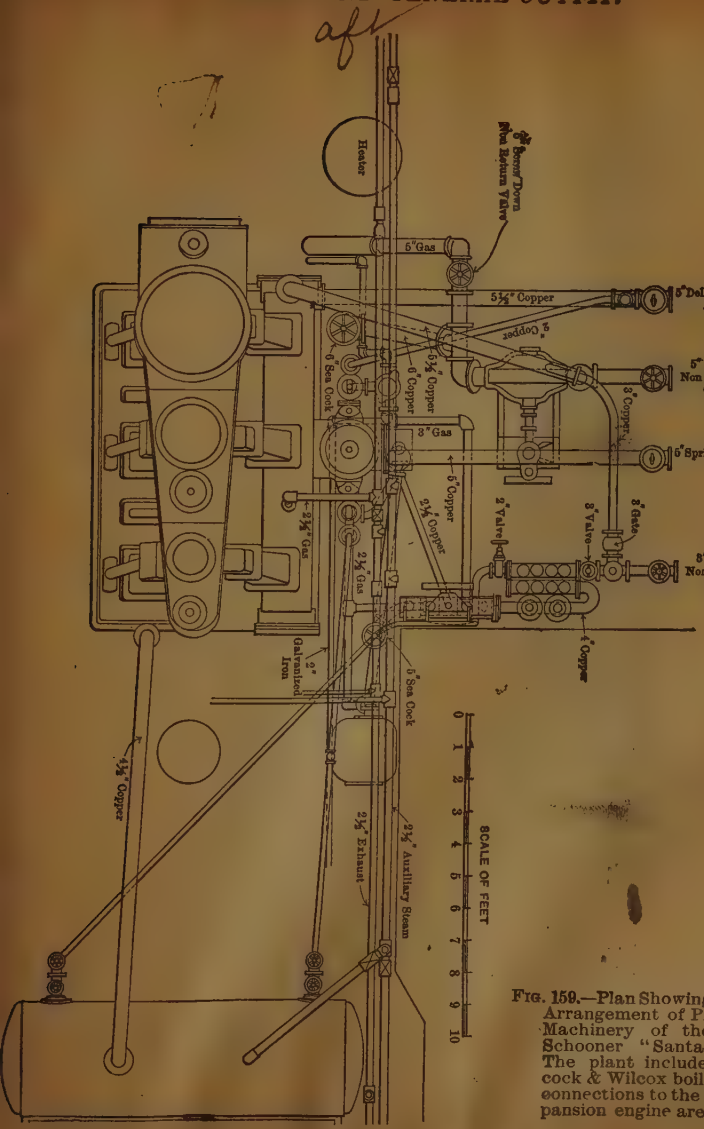


FIG. 159.—Plan Showing General Arrangement of Piping and Machinery of the Steam Schooner "Santa Anna." The plant includes a Babcock & Wilcox boiler, whose connections to the triple expansion engine are shown

other steam pipes is absolutely necessary to prevent such accidents.

Bosses with cocks or valves and drip pipes should be provided, in order to allow the condensed water to be led to the feed tanks or the condenser.

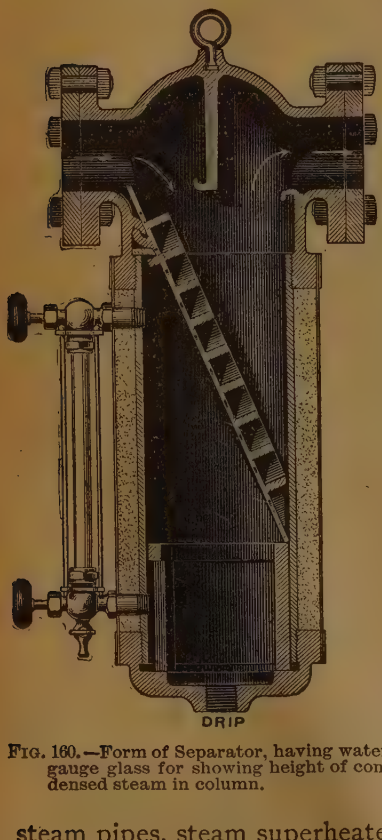


FIG. 160.—Form of Separator, having water gauge glass for showing height of condensed steam in column.

A special permanent separator is frequently fitted on the main steam pipe to strain the steam from the water that is lifted up and carried over from the boiler. Its action is based upon the fact that water adheres to the walls more readily than steam.

If the steam is suddenly deflected in its path, striking against a metal surface, it will deposit most of the water on this surface. If this water be led out of reach of the steam it may be drawn off through a trap to the feed-tank or condenser.

Different constructions are in use, some employing smooth or corrugated plates, others making use of spirals that throw the water off by centrifugal action. To prevent water entering the steam pipes, steam superheaters are employed. Coils of small pipes expose the steam coming from the boiler to the heat of the uptake gases, raising its temperature and evaporating all water held suspended in the steam.

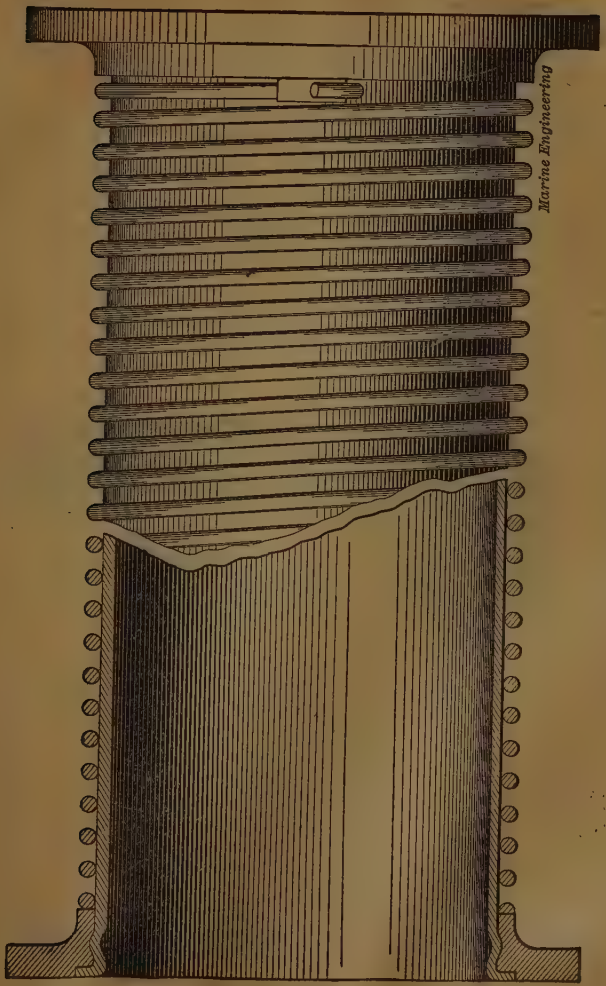


FIG. 161.—Wire-wound Copper Steam Pipe.

Branches from the main steam pipe lead to the starting valves on the intermediate, or low pressure, valve chests, and to the exhaust pipe bleeder valve, for producing condensation and vacuum in advance of the starting of the main engine. The valves in these branches are arranged so that they may be operated conveniently from the working platform.

437. How are the receiver and exhaust piping of the main engine arranged and constructed?

The receiver and exhaust pipes lead the steam from one cylinder to another, or to the condenser. They connect with flanges to the nozzles on the different valve chests and the con-

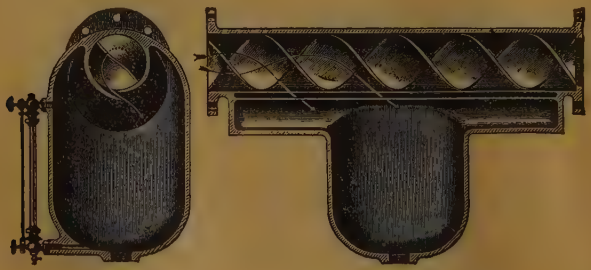


FIG. 162.—**Steam Separator, throwing the water off by centrifugal force.**

denser shell. Large bends or expansion joints allow amply for the expansion and contraction, to prevent strains on the castings and bolts or danger to the tightness of the joints. They are generally of copper, although cast iron or wrought steel pipes are employed in certain engines.

438. How are the auxiliary steam and exhaust pipes arranged and constructed?

The auxiliary steam pipe is provided to supply steam to the different auxiliaries, independent of the main steam pipe. It connects with the smaller auxiliary steam stop valve on the

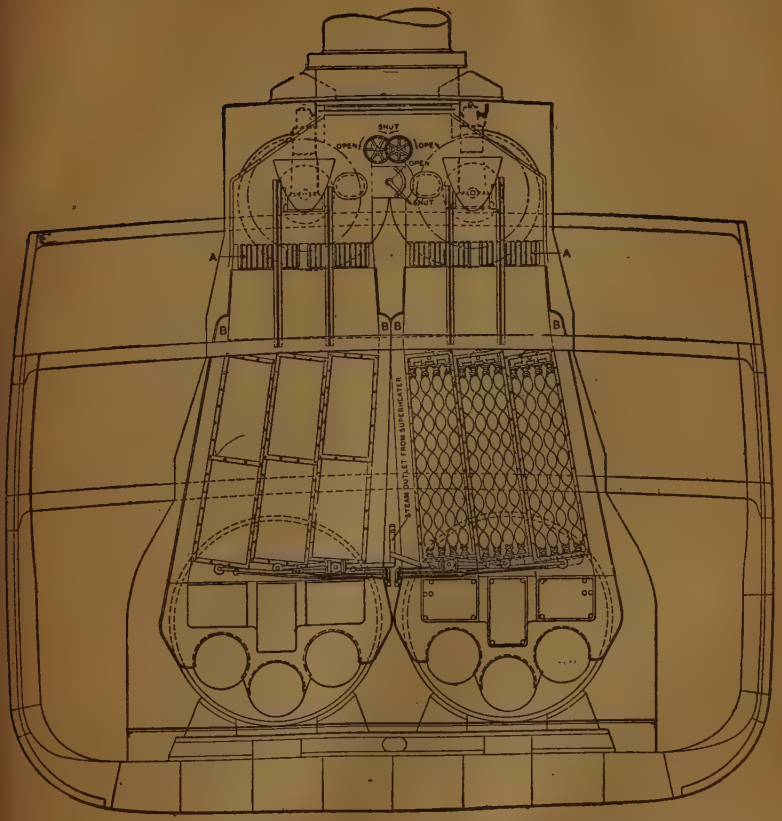


FIG. 163.—Section through the Boiler Room of the Steamer "Inchmarlo," showing the induced draught and superheaters. The air for the induced draught is drawn in through the slides, A, at the front of the air tubes on the spar deck, passing down through the ducts, B, to the furnaces. (See side view in Fig. 164.)

boiler, and has often a pressure-reducing valve near it. This reduces the admission pressure for the auxiliaries; superheats the steam to a certain extent, and cuts down condensation losses. The pipe is of copper, brass or iron, with flange connections for the main run, and flanged, or screwed, connections for the smaller branches.

Arrangements are made similar to those in the main steam pipe for expansion by bends or expansion joints; also provisions for complete drainage of all pockets. There are branches to all the auxiliaries, as well as to the sea-valve casings under the valves, to blow impurities, obstructions and ice out of the strainers. Valves are generally fitted in the branches near the auxiliary steam pipe and near the engine of the auxiliary.

The auxiliary exhaust pipe is somewhat larger, but arranged in the same manner as the auxiliary steam pipe. Its branches collect the exhaust steam from all the auxiliaries, and lead it either to the feed-heater, to the main or auxiliary condenser, or through the escape pipe into the atmosphere.

Occasionally, for better economy in the use of the steam for the auxiliaries, the auxiliary exhaust pipe has a connection to the low-pressure valve chest, securing thereby an additional amount of work in the low-pressure cylinder from the exhaust steam.

Branches from the auxiliary steam pipe lead to the different compartments of the hold for fire-extinguishing purposes.

RULE II, 27.—The thickness of and pressure allowed on main steam pipe constructed or riveted iron or steel plates that have been stamped and tested as required by section 4430, Revised Statutes, shall be determined in the same manner as required by section 4433, Revised Statutes, to determine the pressure allowable on boilers.

The thickness of and steam pressure allowable on all lap-welded or solid drawn steam pipe of wrought iron or steel shall be determined by the following formulas:

$$T = \frac{P \times D}{10{,}000} + .125$$

$$P = \frac{(T - .125) \times 10{,}000}{D}$$

Where P = pressure of steam allowable in pounds. T = thickness of pipe. D = diameter of pipe.

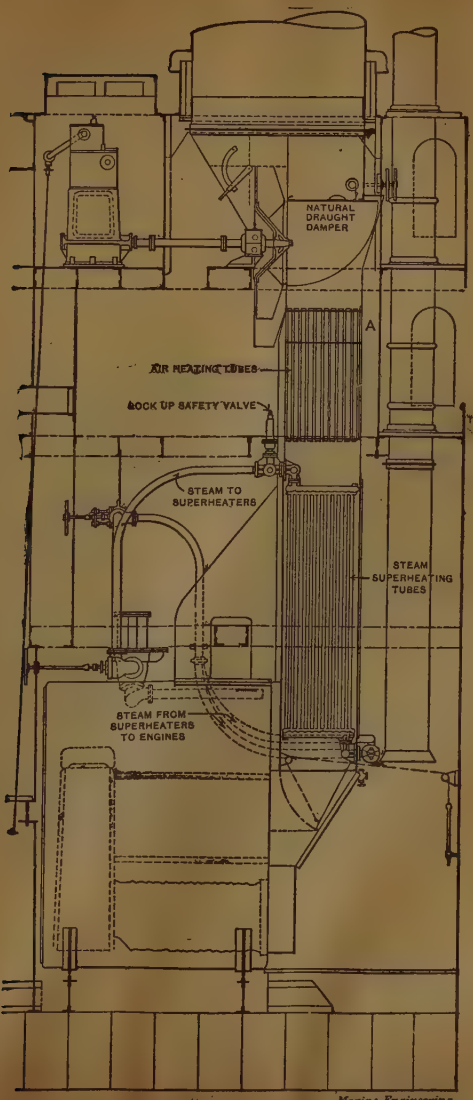


FIG. 164.—Side View of the Superheater, etc., shown in Fig. 163.

439. What are the principal water pipes?

(1.) Condensing plant piping, comprising the circulating and air-pump suction and discharge pipes.

(2.) Feed pump piping.

(3.) Bilge and ballast piping, largely in suction and low-pressure leads.

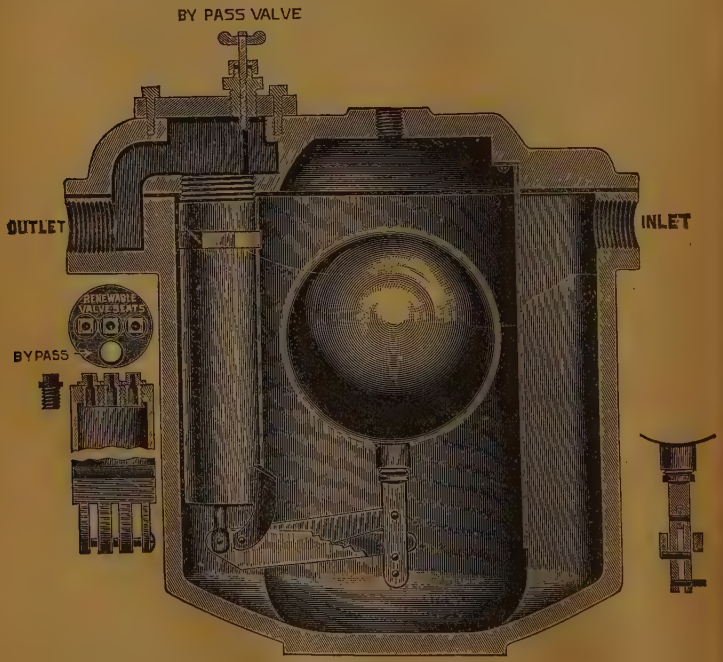


FIG. 165.—Steam Trap.

(4.) Donkey, fire main, ash ejector, deck wash, evaporato and other such systems of piping, which are largely discharg and high-pressure leads.

(5.) Water service piping.

440. How is the condensing plant piping arranged and constructed?

The pipes required for the operation of the condensing plant are the air-pump suction and discharge pipes for jet condensers, while for surface condensers the supply and discharge pipes of the circulating pump are added.

The air-pump suction is frequently a part of the condenser shell or bed plate, and is, in that case, usually a cast-iron chan-

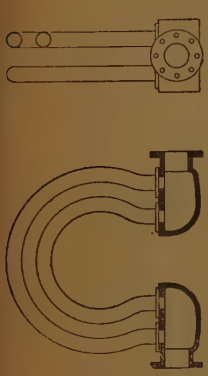


FIG. 166.

FIG. 167.

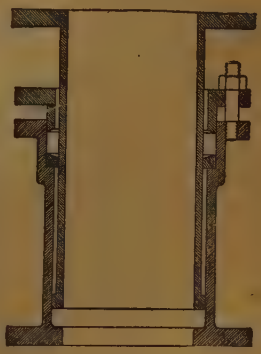


FIG. 168.

FIGS. 166, 167.—Copper Expansion Loops and Joints, showing details of connections.
FIG. 168.—Composition Slip Joints for Steam Pipes, showing telescopic arrangement to compensate variations of length under differing temperatures. (See Section 436.)

nel-way with a facing for the air pump. If a special pipe is itted, it is generally a copper pipe, with flange connections of sufficient strength and tightness to effectively resist the atmospheric pressure and maintain the vacuum.

The injection pipes for jet condensation are frequently provided also with surface condensers for cases of emergency. They are often in duplicate, one from the side, the other from the bottom of the ship, and have the cocks, or valves, to pass the water into the condenser, arranged in a position easily accessible for operation from the working platform.

The air-pump discharge pipe, generally of copper, is co nected to the hot well, at a sufficient height to secure a goo head of water above the feed pump suction and discharges abov the water line of the ship. The hot well has a copper ver and overflow pipe to the upper deck, to the side of the ship to the feed tank.

The circulating pump section pipe connects directly to th side, or bottom, of the ship, with a branch leading to the lov est point of the bilge. The outlet of the pump leads to to or bottom, chest on the condenser, in such a way that any a collection may be drawn off through an air cock at the highe point. The outlet from the condenser connects to the side the ship above the water line.

The material of this pipe, carrying salt water, is always co per. The pressure is small and the thickness of the walls co respondingly light. The parts have flange connections.

441. How is the feed piping arranged and constructed?

The feed piping carries the feed water to the boiler, and co sequently must have great strength and tightness to resist th heavy pressure which, at times, may rise even above the ord nary working pressure of the boiler. There are two indepen ent leads of feed piping, corresponding to the main and au iliary feed pump.

The pipes are of steel or copper, with flanges or screw f tings in small sizes.

442. How are the bilge and ballast piping arranged a constructed?

The bilge and ballast piping lead the water from the diff ent compartments to the manifolds and pumps in or near t machinery space.

They are led horizontally, frequently exposed to corrodi influences through long distances. Copper piping is the m

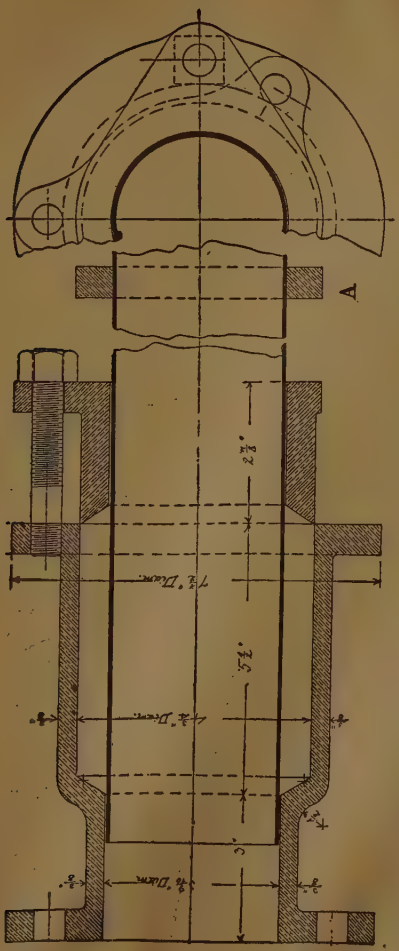


FIG. 169.—Details of an Expansion Joint on a Copper Steam Pipe. The copper pipe is shown by the black lines. A is the preventer ring brazed on the copper pipe.

durable, lending itself readily to many bends and crooke leads, necessitated by the passing of numerous obstacles.

In iron hulls, however, its low position, within reach of th bilge water that would set up a destructive galvanic action b tween copper pipes and hull, induces many engineers to prefe galvanized wrought iron or cast iron pipes of heavy thickness thus securing a reasonable durability. Lead piping is use with advantage in places not exposed to internal injury.

443. How is the piping for the donkey, fire main, ash ejector, evaporator, etc., arranged and constructed

These general service pipes lead from the pumps to differen places of operation, generally under pressure, and contain sometimes fresh and sometimes salt water. They are best mad of copper, as it is the most durable material under slight tem perature elevations, without excessively high pressures.

The connections are generally made by flanges.

444. How are the water service pipes arranged and con structed?

The water service pipes serve the purpose of supplyin cooling water to the machinery parts liable to become heated

Thus, from a sea valve, a complete system of pipes is le to the main bearings, the crank pins, the slipper guides, th cross-heads, the link gear, the eccentrics, the thrust-bearin and all shaft bearings with small cocks or valves at the en that regulate or shut off the supply. Frequently, univers joints are fitted for the extreme ends of the branches for d rection of the stream to the place most in need of it.

The piping is generally of brass with screwed fittings, oft only in small sizes.

RULE II, 27.—All copper pipe subject to pr ssur shall be flang d ov r or outward t depth of not less than twice the thickness of the material in the pipe, and such flanging sh be made to a radius not to exceed the thickness of the pipe. On boilers whose construct was commenced after June 30, 1905, no bend shall be allowed in copper pipe of which

445. How are the pipe connections made?

The pipe connections unite the several smaller sections of tubing into one continuous line. The connection should have the same strength and tightness as the pipe itself, sometimes a higher strength, and also allow of easy and rapid connecting and disconnecting. The connections are generally of the same, or similar, material as the pipes, being for copper, brass or lead pipes of composition, while for iron and steel pipes they are of cast or malleable iron, semi-steel and cast steel. Two methods of connection are employed; the first one using two independent flanges on the ends of the pipes, clamped together by bolts; the second using one independent fitting, into which the ends of the pipes are screwed.

RULE II, 27.—*Continued,*

radius is less than one and one-half times the diameter of the pipe, and such pipe shall be so led and flanges so placed that they may be readily taken down if required. Such pipes shall be protected by iron casings when run through coal bunkers, and shall be clear of the coal chutes. The thickness of material, according to the working pressure, shall be determined by the following formula:

$$T = \frac{P \times D}{8{,}000} + .0625.$$

Where T = thickness in inches.
P = working pressure.
D = inside diameter of pipe in inches.

EXAMPLE

Required the thickness of material of a 5-inch copper pipe for a working pressure of 175 pounds per square inch.

Substituting values, we have

$$T = \frac{175 \times 5}{8{,}000} + .0625 = .171 \text{ inch.}$$

Provided, however, That all copper pipe subject to pressure and installed for use on steam vessels after July 1, 1911, shall have a thickness of material according to the working pressure, to be determined by the following formula:

$$T = \frac{P \times D}{6{,}000} + .0625.$$

Where T = thickness in inches.
P = working pressure.
D = inside diameter of pipe in inches.

EXAMPLE

Required the thickness of material of a 5-inch copper pipe for a working pressure of 175 pounds per square inch.

Substituting and solving, we have

$$T = \frac{175 \times 5}{6{,}000} + .0625 = .208.$$

446. What are the characteristics of flange connections?

Flanges are the most important connection for all pipes ov two or three inches in diameter, and for the highest pressure since a very uniform clamping pressure can be obtain through the numerous bolts in a large flange.

They require, however, greater preparation for making th joint, as the flange faces must be square to the longitudin

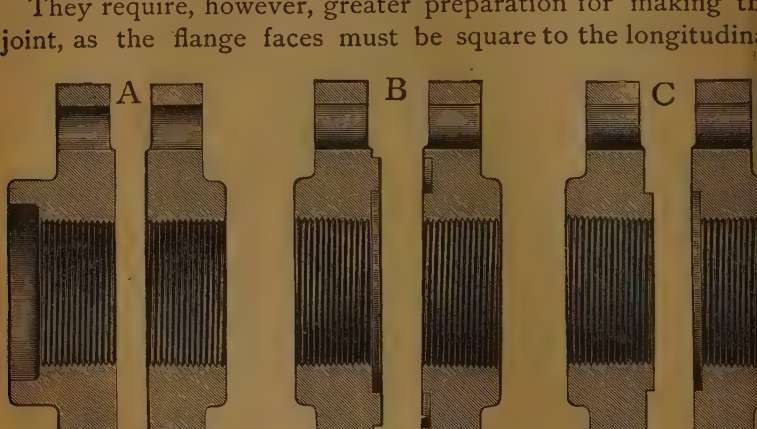


FIG. 170.—Three Styles of Flange Connections. At A, the two smooth faces brought together and bolted; at B, a circular lug fits into a circular chan insuring tight joint; at C, the ends are cut so that one fits into the other.

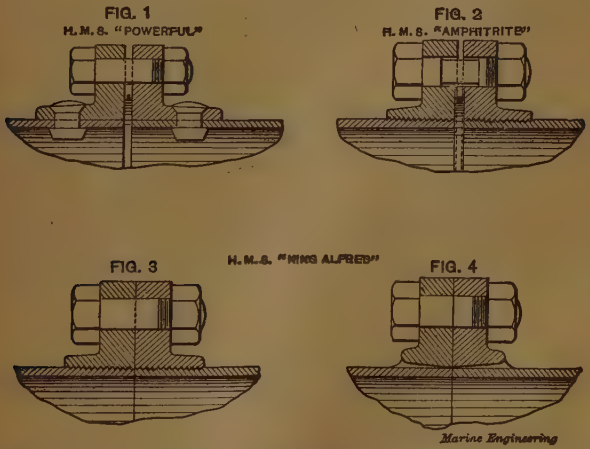
axis of the pipe. They must be tightly fastened upon t pipes, the bolt-holes to correspond; the packing must be fitt smoothly and neatly between the faces, and the bolts drawn uniformly.

Outlets or bends are made by special flanged fittings composition for copper pipes, and of cast or malleable ir or cast steel, for steel and iron pipes.

The flanges should be stiff, to avoid all springing, and ha numerous bolts with close spacing, particularly for high pre ures. The faces of the flanges are frequently smooth or w

low male and female projections that, with high pressure, prevent the packing from being blown out. There is generally provided between the flanges some packing material of soft metal, like copper or Babbitt, or rubber gaskets, or red lead cement, with canvas, or paper, slightly compressed and filling all unevenness in the faces.

The flanges are provided with small bosses to give a longer bearing on the pipes. For steel pipes they are tightly fas-



IG. 171.—Several Varieties of Flange Connections Used on British Warships. The constructions shown in Figs. 1 and 2 were used for steel pipes having a copper ring between the pipe ends. They were unsatisfactory on account of corrosion. Fig. 3 is a steel pipe joint with steel flanges fitted closely. Fig. 4 is a copper pipe joint with flanges brazed to the pipe.

ened by screwing or riveting, with the ends of the pipes expanded into slightly conical holes and beaded over into a recess in the face of the flange.

For copper pipes the flanges are brazed or riveted on, and the ends of the pipes beaded over into recesses. Cast-iron pipes are sometimes cast with flanges, while wrought-iron pipes may have the flanges welded on.

447. What are the characteristics of screwed fittings?

The screwed fittings have universally right-hand thread, an therefore, cannot be removed out of the middle of a pipe lin The joints are very easily made, as the thread serves at th same time, for tightening and drawing the pieces togeth longitudinally. No special packing is required, except som red lead on the threads, to fill the small interstices. Outle and bends are similar to the regular couplings in the scre thread connection, being made with the greatest ease.

Screw-fitting connection is limited to small pipes, up about two or three inches in diameter for convenience handling on shipboard, where space is usually restricted f mounting and dismounting of the pipes. To make access the line more convenient, flanges, or unions, are fitted at inte vals, to allow disconnecting without longitudinal movemer A union is a throw-over nut that leaves the pipes stationa while it turns itself. It hooks behind a collar on one pipe e and screws into the other one, thus clamping them tightly t gether with a packing gasket between.

448. How are the pipes passed through bulkheads a sides of tanks?

Pipes passing through bulkheads, or the sides of tanks, a preferably independent from them in their joints. For th purpose a short piece of flanged, or screwed, pipe is push through the bulkhead and connected to it by a large bolt collar in the middle of the pipe. The short nipple, reachi out from the bulkhead on either side, thus affords convenie connection by bolts, or coupling, to the next length of pipi

Another method is that of fitting a divided stuffing box the bulkhead over the pipe, which thus gains the advantage sliding through the bulkhead upon expansion or contraction feature particularly desirable for steam pipes.

449. What is the duty of valves and cocks?

Valves and cocks serve to place the whole, or a part, of the pipe lines in or out of communication with the working parts of the machinery plant. They may, at the same time, exercise a regulating influence upon the amount and velocity of the working fluid.

Their necessary characteristics are permanent strength and tightness, under frequent and rapid making, or breaking, of the communication. Ease and quickness of operation, with small wear and repairs of the working parts, and a certain indifference to the quality of the working fluid are qualities highly desirable in valves and cocks.

450. What is the distinguishing difference between valves and cocks?

The distinguishing difference between valves and cocks is in the amount of bearing and tightening surface. Valves bear and grind upon a narrow and small seat only, when in, or near, the closing position, while cocks bear and grind always upon a wide and large seating surface.

The wear in valves is, therefore, much less, and they are kept tight much more easily under high pressure than cocks, leading to a complete replacing of cocks by valves for all places where frequently used.

451. What kinds of valves are used in marine practice?

(1.) Globe valves of straight-through or angle connection.
(2.) Gate valves.
(3.) Butterfly valves.

452. What are the characteristics of the globe valves?

The globe valves are distinguished particularly for their strength and tightness. The valve moves and is pressed squarely against its seat by the closing pressure in valve stem or working fluid. The angle connection is very frequently found in

marine practice as making the path through the valve less crooked and tortuous than with the straight-through connection.

The deflection in the path through the valve is an objection, in the globe valve, as producing considerable friction, and, consequently, loss of power, with higher speed of the working fluid.

Steam stop and feed check valves are usually of the globe pattern.

The valves themselves may be operated by screwing or sliding stems, or may be entirely automatic, like pump valves, fitted only with a stem for limiting or preventing the automatic lift.

Some engineers prefer to have the excess pressure below the valve, which has the advantage of relieving the stuffing-box of a permanent exposure to pressure, and of ease and rapidity in opening the valve with the help of the pressure. The disadvantage is that the full pressure must be resisted by the valve stem in the closed position.

Other engineers prefer to have the excess pressure on top of the valve, thus aiding in tightening and relieving the valve stem of pressure, except for opening, which is, in large valves, necessarily somewhat slow and laborious. At the same time the stuffing-box is permanently under the influence of the pressure and requires more care and attendance.

To overcome the difficulty of opening large valves, by-passes in form of small valves are often fitted, or a balanced arrangement is fitted, combining two lift valves or combining one lift valve with a sliding, packed piston.

453. What are the characteristics of the gate valves and butterfly valves?

The principal distinction of the gate valves and butterfly valves is that the passage through them is straight and undeflected, forming, practically, a part of the section of the

pipe. The friction resistances in the valve are, consequently, not much more than in the pipe, and higher speed of the fluid can be successfully employed. The valves being moved, or swung, across the flow, are not quite as reliable in regard to

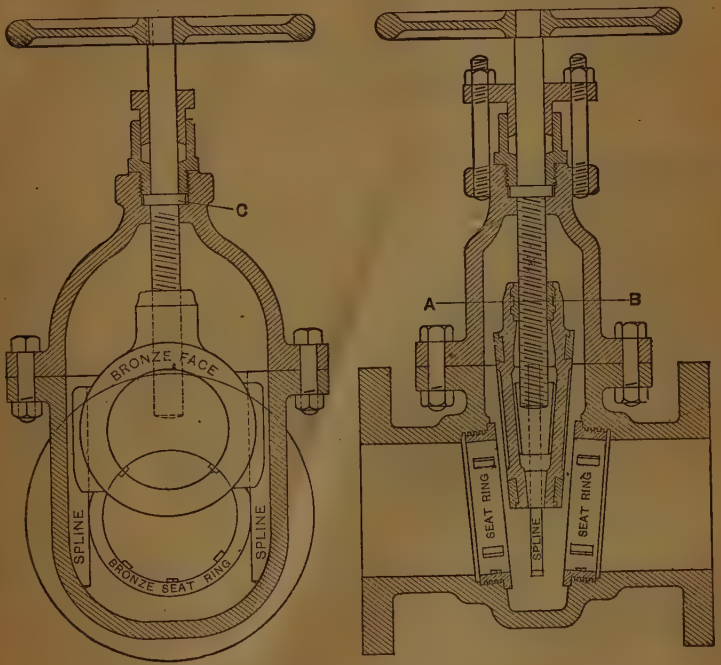


FIG. 172.—Two Sections of a Gate Valve, showing constructional details.

strength and tightness as globe valves, although gate valves, being wedged between conical seats in the closing position, are successfully employed for even the highest pressures.

Butterfly valves do not overlap their seats and are, therefore, not fit for sustaining large excess pressure. They are useful

however, on account of ease of operation and being light, cheap and fully balanced.

Gate valves of large dimensions require smaller by-pass valves, as the friction on the seat proves too severe, under heavy pressure, for the strength of the spindle, or too slow for practical requirements.

A special form of gate valves are the sluice valves, used in water-tight bulkheads, to allow water to pass from one compartment into another.

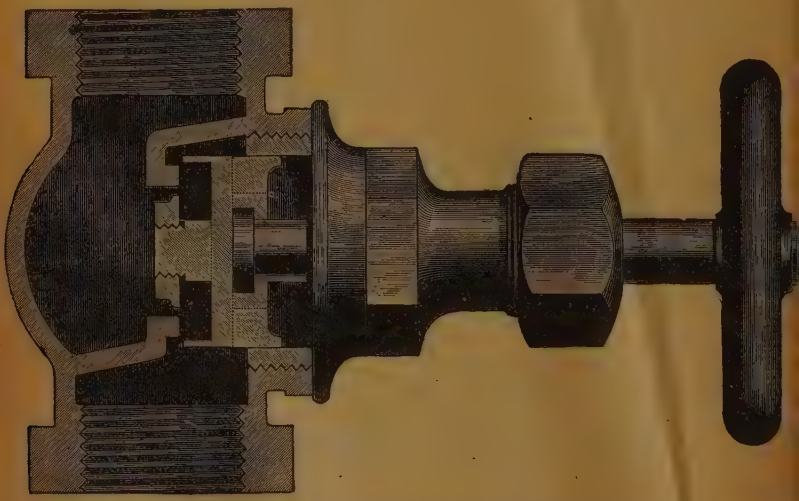


FIG. 173.—Section Through a Type of Globe Valve.

454. How are the valves arranged and constructed?

The valves are arranged to afford ease of operation. They are fitted at the ends of the main, or branch, pipes near the machines, or at the side of the ship, and afford, thereby, the chance of disconnecting, replacing or repairing certain parts without disturbance to others. They should be placed in positions easily accessible to the engineers, as rapidity of opera-

tion may be of vital importance to the safety of the machinery and attendants.

The valves and their seats, as well as stuffing-box mountings, are generally of bronze to prevent corrosion or rusting. In small valves the casing and spindles may be of composition, but for larger ones the casings are generally of cast iron, or steel, and the spindles of wrought steel. The connections to the pipes are made by bolted flanges, or screwed sockets, cast upon the casings.

The tightening face of the valve is constructed in different ways; some constructions employ bronze on bronze, others rubber, vulcanite or soft metal removable discs in the valve on bronze seats, while, in gate valves, bronze gates on Babbitt seats are used for water service of low temperatures.

The spindles and valves are raised generally by screwing. The threads of the nut are sometimes cut into the cover casting, the nut is held by the cover below the stuffing-box; or, as generally used in large valves, the threads are in a bridge, held down to the cover by two standing bolts, being thus easily fitted and replaced when worn.

455. How are the cocks arranged and constructed?

Cocks give a straight passage without deflection to the flow of the liquid and are useful in small sizes on account of the rapidity of their operation. They prove most desirable when only occasionally used, and when the liquid is fairly clean and free from grit.

In cases where a three-way connection and a rapid change from one inlet, or outlet, to another is desired one cock can take the place of two or three valves with advantage. In this case there is a third or bottom outlet provided on the casing of the cock. The connections are made by bolted flanges or screwed sockets.

Cocks are generally conical plugs fitted into casings, carrying

the inlet and outlet openings. The plug overlaps the openings, at the sides and ends, sufficiently to prevent any leakage through the ground joint. A square is fitted on the top for the attachment of the wrench or handle supplying the leverage for turning the cock. A nut and washer at the bottom hold the cone tightly down upon its seat, and allow a certain amount of drawing-up to compensate wear and consequent re-grinding of the plug. Cocks are sometimes packed at the top and provided with tightly closed bottom, to prevent any leakage to the outside.

To insure complete tightness around the circumference, strips of asbestos, or similar packing, are sometimes fitted, bearing longitudinally against the wall of the plug. Cocks are generally of composition throughout.

456. How are the sea-valves arranged and constructed?

The sea-valves are fitted over the openings in the side and bottom of the ship and are of the greatest importance for its safety. They should be strong, tight, simple and permanently accessible under all circumstances.

Their construction is generally in the angle globe form, of cast iron, brass mounted, or entirely of composition. They are connected with the outboard nozzle directly to the side of the ship, or else attached to a box, or cylindrical shaped neck reaching out from the skin beyond the framing, or inner bottom, for more convenient connection. Sometimes several sea valves are attached to one neck and one opening.

The attachment of the box is made by riveting to iron hulls with stiffening rings under the flange, and with bolted flange

Rule II, 27.—All feed and steam pipes of 3 inches in diameter or under may be connected at their intermediate joints by being screwed into flanges, sleeves, elbows, union couplings or other fittings. All such fittings shall be extra heavy. Where such pipes are extra heavy and lap-welded, screwed flanges of cast iron, semisteel, or ferrosteel, having a tensile strength of not less than 20,000 pounds, may be employed: *Provided*, That such flanges shall be made extra heavy and have a depth through the eye of not less than the United States standard length of threaded part for the pipes to which such flange is attached plus the depth of counterbore at back of hub, which depth of counterbore shall be not less than ¼ diameter of pipe.

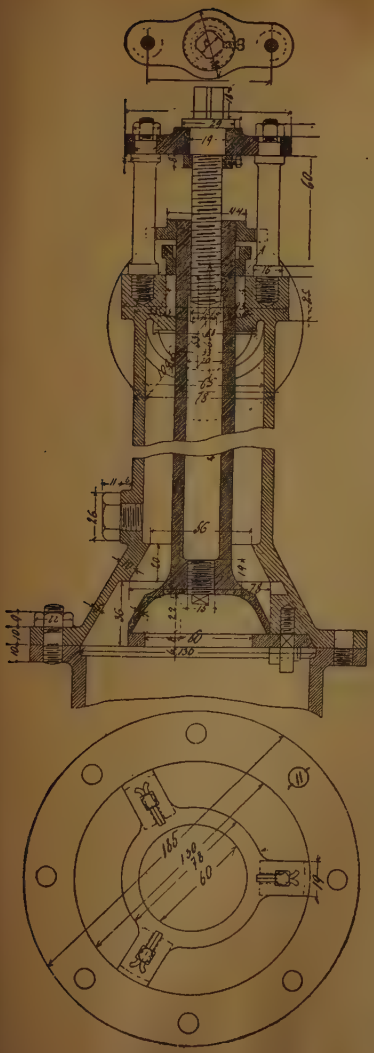


FIG. 174.—Section and Ground Plan of a Kingston Sea Valve.

in wooden hulls. The valves are connected with flanges and numerous studs or bolts.

Strainers are provided for all inlet valves to prevent the entrance of impurities, floating objects, ice, etc. A small steam connection to the neck below the valve allows the blowing-out and cleaning of the strainer.

To prevent injury to iron hulls by galvanic action, zinc rings are fitted around the opening in such way as to be accessible for inspection and renewal.

The outlet or discharge valves of merchant steamers are nearly always above the water line, and, therefore, less likely to prove dangerous to the safety of the vessel.

For this service, check valves or even butterfly valves are considered sufficient.

Great care should be taken in the arrangement of the sea-valve piping that no flooding of the ship can take place through ignorance or carelessness. All pipes leading to the bilge, and standing in connection with sea-valve pipes, should have auto-

matic check valves at the end to positively prevent all possible return of water to the hold.

457. How are the manifold valves arranged and constructed?

Manifold valves are a combination of several valves into one single, large discharge box made of cast iron, brass mounted, or entirely of composition.

They prove very convenient for the engineer, especially with bilge and ballast pipes, which are all led to their own suction valves in the manifold. This, in turn, is connected to the pump by only a single pipe.

458. How are the strainers arranged and constructed?

Strainers are desirable on the open ends of all inlet or suction pipes to prevent the drawing in of impurities and objects that might interfere with an efficient working of the valves or pistons. They are often arranged in basket form and enclosed in a box, with quickly removable cover, so that one basket full of impurities can be quickly replaced by a clean spare one.

459. What element in the distribution of the electric current of the dynamo is analogous to the steam and water piping?

The wiring carries the electric current in the same manner as the piping carries steam and water.

460. What are the important parts of the distributing system of the electric current?

(1.) The switchboard.
(2.) The wiring.
(2.) The lamps and motors.

461. How is the switchboard arranged?

The switchboard assembles in a convenient position the instruments for the control and the switches for the distribution

of the current upon an incombustible support. It is best made of slate or marble set off from the wall of the dynamo room for easy access to all connections. The instruments it carries are, generally, an ammeter, to show the strength of the current; a voltmeter, to show the tension of the current; a rheostat, for regulating the current of the fields of the dynamo; a switch, to break the total current, to cut out any of the external circuit and safety fuses, or to prevent any circuit from carrying more than its safe load of current.

The two poles of the dynamo connect by heavy cables to the bus bars, from which the external branch circuit starts.

462. How is the electrical wiring arranged?

The electrical wiring carries the current to the lamps or motors. It is of the best copper, thoroughly insulated to prevent short-circuiting. On shipboard it is generally arranged on the two-wire principle, with the lamps, or motors, in parallel, which system allows an easy cutting-out of any desired number. Frequently a number of lamps are connected to one junction box, which is supplied from the switchboard through two heavy wires.

The wires are protected from external injury to themselves, or their insulation, by being placed in wooden mouldings, or in iron tubes, lined with insulating material. These latter are, necessarily, in exposed places, fire rooms, engine rooms, around the decks, in the holds, etc. The junction boxes have safety fuses, and connections arranged in incombustible porcelain or lava blocks.

463. How are the lamps and motors arranged?

The lamps are arranged in substantial supports with good protection to the insulation of the wires at their connection. For exposed places extra globes or wire protectors are provided to prevent breaking of the bulbs.

The motors are fitted on substantial foundations, with switches for handling in convenient positions.

464. What fittings are provided in the engine room for the convenience of the engineer?

(1.) Several gauges and a clock on the gauge-board.
(2.) Thermometers.
(3.) Revolution counter and speed indicator.
(4.) Speaking-tubes, mechanical telegraphs and gongs.
(5.) Governors.

465. How is the gauge-board arranged?

The gauge-board is generally an ornamental tablet of wood, or metal, in a position easily seen by the engineer on the working platform. It carries gauges, indicating the pressure in the boiler, the receiver and the vacuum in the condenser.

A clock is generally also fitted on the gauge-board for observation of the watches.

466. How are the thermometers arranged?

Thermometers are arranged for taking the temperature of the hot well water of the injection, or circulating, water at inlet and at outlet. Sometimes thermometers are provided for taking the temperature of the steam, at the throttle, receivers and exhaust pipe, especially with superheated steam.

467. How are the revolution counter and speed indicator arranged?

The revolution counter gives the total number of revolutions made. It is driven from the engine by gears or ratchet and is, therefore, arranged near it. It is sometimes on the gauge-board or in a position where easily seen.

Special speed indicators, the so-called tachymeters, driven from the engine, give the number of revolutions per minute.

In single cylinder beam engines, where the engineer cannot

see the crank moving, a dial is arranged at the platform that shows through gear connection to its hand how the crank stands. The engineer can thus bring the engine to a stop in a position convenient for an effective start.

468. How are the speaking-tubes, mechanical telegraphs and gongs arranged?

For communication from the working platform to the pilot house of the ship, and to the chief engineer's state-room, speaking tubes of copper or brass are provided with whistles and mouthpieces. The firerooms also are, in large installations, connected to the platform for more rapid communication.

The orders from the pilot house for starting and stopping are frequently transmitted by mechanical, or electrical, telegraphs, that show on a dial the instruction to the engineer. To prevent errors the engineer often repeats the orders in return.

Gongs are provided to give the orders in audible form, while a small jingle bell calls the attention of the engineer to the orders that will follow.

Telegraphs and gongs are usually of composition, with wire or chain pulls, leading over sheaves, in as straight a lead as possible, from the pilot house.

469. How is the governor arranged?

Governors, for the regulation of the speed of the engine, are not very popular with marine engineers, as being not quick and decided enough. Particularly with multiple cylinders, a change in the steam supply of the high-pressure cylinder is felt only after some time. The best arrangement effects the reversing engine, putting it and the links on the centre position, and, thereby, stopping all cylinders.

Governors may prove valuable in accidents, like the dropping-off of the propeller, or the breaking of the shafting, to prevent the running away of the engine.

470. What provision is made for easy access to all parts of the machinery plant?

Access to the machinery for inspection and operation by the engineer is facilitated by flooring, platforms, ladders and handrails.

The flooring is arranged above the framing of the ship at a height convenient for access to all the main bearings and auxiliaries in the engine room and for access to the furnaces and ash-pits in the boiler room. It consists of wrought or cast iron, corrugated or checkered plates, which afford a substantial and secure foothold, even if wet or greasy and under motion of the ship in a seaway.

To prevent tools or nuts and bolts from falling into the bilge, the flooring should fit perfectly tight around the machinery. It should also be well bolted to the supporting beams, so as not to get adrift under wash of bilge water or movements of the vessel.

The supporting beams are generally of angle iron, bracketed to the framing of the ship and supporting stanchions. Since large quantities of coal or ashes have occasionally to be supported by the flooring in the boiler room, it should be always strong enough for this purpose.

The platforms or galleries are provided in one or more tiers around the engine or boilers to allow convenient access to all the different parts and valves, which may need the care and superintendence of the engineers. To admit light and air to the floor these platforms are generally iron gratings of round or square bars, fitted in flat-bar frames, and supported on ledges, or brackets, from the walls of the casings, beams above, or other convenient points of support. Where they pass directly over working parts of the engine, a wooden board or pieces of linoleum are sometimes fitted on the grating to prevent dirt from falling into the bearings.

To establish connection from one platform or deck to another ladders are provided. These are made of iron, and are similar in construction to the platforms, by having round or square bars, fitted at suitable intervals between the flat iron bars that connect the landings. Handrails of round brass tubes, or iron bars, are fitted to secure safe passage even in heavy seaway. Handrails all around the moving parts of the machinery provide the necessary safeguards to the engineers and prevent accident under violent movement of the ship.

Fig. 175.—Hydraulic Pulling Jack.

471. What provisions are made to assist the engineer to greater familiarity with the machinery and so guard against mistakes?

The most thorough familiarity and rapid distinction of any particular part of the machinery may prove of the highest importance to the safety of the ship and the attendants. Every effort is, therefore, made to allow the readiest passage around all parts and to illuminate the entire machinery plant, so that the condition of any portion of it may be observed from a distance, and even from the working platform.

To prevent mistakes in the handling of the valves and levers, all hand-wheels and handles are designated by large, legible labels and have indicators to tell if they are open or shut. A great help is the painting of the pipes or their lagging with strong and distinctive colors, choosing a well defined and described schedule which may be readily learned by all attend-

ants. The paint of the engine room, and the stationary machinery parts, is frequently of some light shade, which, although more easily soiled, reflects the light better.

Illumination with electric lights can be established successfully everywhere, even between and around the boilers, coal bunkers and passages.

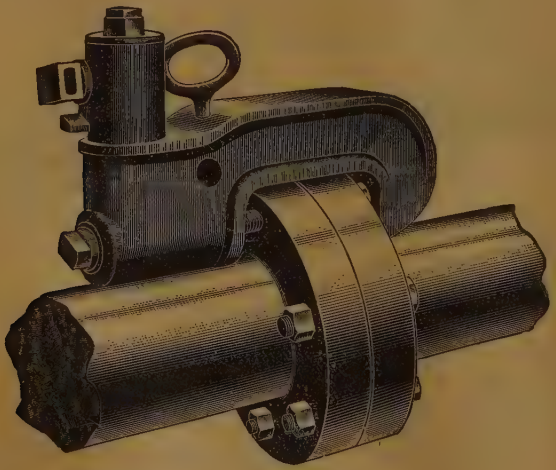


FIG. 176.—Hydraulic Bolt Extractor.

472. What provision is made for spare parts, tools and fittings?

Spare parts, tools and fittings are supplied in varying quantities, according to the length and character of the voyage. Coastwise and river steamers, being always near repair shops, require only a small outfit, while sea-going, trans-Atlantic steamers are prudently provided with a very large outfit.

These spare parts require considerable room, which is always at a premium, on board ship. Consequently, a careful consideration of stowage should be made by the engineer. Hanging

of the smaller parts on the walls of the engine room casing is one popular method of stowage; while the larger parts find secure fastenings upon special blocking on the flooring, the bilge or hold stringers, or other spaces not occupied by the machinery. If the space in any way allows, a special room off the engine room is alloted entirely to a workshop, where a bench and vises are fitted, racks for wrenches and tools, and, occasionally, even a drill-press and a lathe.

In the fire room, racks are provided for the firing tools, coal hammer, hose for cooling ashes, etc. Lifting arrangements are provided for all the heavy parts of the machinery; a crane beam usually running above the cylinders with lifting tackle of hydraulic, differential or helical gear.

Movable hydraulic, or screw, jacks serve on numerous occasions most effectively for all kinds of lifting or propping-up of less accessible parts. Eye-bolts and jack-bolts are arranged for in all parts that are likely to be handled in order to facilitate and accelerate the work, as much as possible, in the necessarily crowded quarters.

The engineers of larger steamers generally find a desk with drawers at the platform for the keeping of the log-book, accounts of the different supplies, etc., also for storing the indicators and their cards, a planimeter, test-gauges, thermometers and salinometers.

Emery paper, washers and sheets of rubber or other material, with scissors and special circular cutters, are frequently stored in drawers for distribution by the engineer.

All the prepared packing for covers, stuffing-boxes, etc., is stored in drawers, ready for immediate use, marked and labeled as asbestos, metallic, rubber, hemp or other variety of packing, for the different requirements.

In convenient places of the engine or boiler room bags or tanks for Babbitt metal, mineral wool, felting and bagging are

placed, also for clean and for dirty cotton waste, for paints of different colors, and red and white lead.

Oil tanks are provided for cylinder oil, engine oil—sometimes for a special grade of dynamo oil—for tallow and for kerosene. For convenience of working, a small tank with a lock, holding enough oil for about twenty-four hours, is provided in a position convenient for the oilers. A sheet brass leakage box is arranged under the faucet of this tank and holds a copper funnel, a quart or half gallon measure and three or four oil cans.

To store fresh water, one or more large, well-stiffened wrought-iron feed tanks are provided in the inner bottom or in any convenient place. They connect with valves and piping to their respective pumps, and are provided with manholes, air vent or overflow pipes, drain-cocks and water gauges.

The bunkers containing the coal are, in large ships, provided with trolleys, on which the coal is transported to the furnaces in buckets.

The bunker doors are sometimes of the vertical, sliding type, or only wooden boards are fitted over the door openings. Coal scuttles are distributed in the decks above, to allow a good distribution and as high a stowage as possible of the coal in the bunker.

Illumination and ventilation are, or might be, of such extent as would facilitate and accelerate the laborious work in these necessarily gloomy places.

PART SEVEN.

CARE AND OPERATION OF A MARINE ENGINE.

CHAPTER TWENTY-ONE—LUBRICANTS AND LUBRICATION.

CHAPTER TWENTY-TWO—PACKING AND PACKING MATERIALS.

CHAPTER TWENTY-THREE—CARE AND OVERHAULING IN PORT.

CHAPTER TWENTY-FOUR—LAYING UP A MARINE ENGINE.

CHAPTER TWENTY-FIVE—CARE AND OPERATION UNDER WAY.

CHAPTER TWENTY-ONE.

LUBRICANTS AND LUBRICATION.

473. What is the fundamental duty of lubricants?

The fundamental duty of all lubricants is to reduce friction between two bodies, one of which is in motion while the other is at rest.

474. What is friction?

Friction is the resistance between the contact surfaces of two bodies which prevents easy sliding of one upon the other, and requires a certain force to effect the sliding.

475. Upon what does the magnitude of the friction depend?

(1.) Upon the hardness or softness of the materials.

(2.) Upon the pressure that the bodies exert against one another.

(3.) Upon the condition of the surface of contact, whether smooth or rough.

(4.) Upon the speed with which one passes over the other.

476. What kinds of friction are distinguished?

Friction may be distinguished as friction of rest and as friction of motion. The former must be overcome when one of the bodies starts its motion, and is greater than the friction overcome during established motion of the body.

Another distinction is between sliding and rolling friction. The former must be overcome, where the same parts of the moving body are always in contact with the support, as in the cross-head slipper on the slipper guide, and rods in their stuffing-boxes. Rolling friction must be overcome where new

parts of the moving body come into contact with the support as a crankshaft journal in its bearing.

477. What is fluid friction ?

Fluid friction is that existing between the different moving particles of a liquid or gaseous fluid.

478. What influence have the materials of the moving bodies upon friction ?

The materials of the moving bodies have a certain influence upon friction, depending upon their degree of hardness, as the harder the surface the more easily is the smoothness retained.

With thorough lubrication the material itself is of no great importance, as the lubricant keeps the bodies from direct contact.

The anti-friction metals, as commonly used in bearings generally do not reduce friction directly, but act by being easily reduced to a smooth surface, due to their softness.

479. How does lubrication reduce friction ?

Lubrication reduces friction by keeping the bodies separated by a film of the lubricant, thus preventing their direct contact and in substituting the fluid friction of the particles of the lubricant for the friction of the solid bodies.

The completeness of this substitution depends upon the completeness of the supply of lubricant, as, with scant supply the friction will be more like the friction between the bodies than that between the particles of the lubricant.

480. What takes place when the lubrication is insufficient

If the lubrication is insufficient for keeping the moving bodies separated, heating is apt to take place under the solid friction, and, at last, "seizing," by which the smoothness of the surface is rapidly destroyed.

481. What influence has lubrication upon the economy of running marine engines?

The influence of lubrication on the economy of running marine engines may be considered in regard to three points:

(1.) Frictional resistance in the engine.

(2.) Wear on the bearing surfaces, heating, repair and delay by interruption of voyage.

(3.) Cost of lubrication.

482. How is the friction of the engine affected by the lubrication?

The frictional resistances in the engine may be large or small, as the lubrication is poor or good.

If the friction of the engine at full power is as much as 14 per cent., or more, of the total power, it is decidedly advantageous that another two or three per cent. of the total power be saved by efficient lubrication, saving the same percentage in coal consumption.

483. How is the wear and tear of the engine affected by the lubrication?

Ample lubrication can effectively prevent heavy wear, thus saving considerable labor and money. With good lubrication, the bearings will keep a smooth surface, will not heat, and will require no extra attendance. No stopping of the engine need occur on the voyage, and breakdowns will be less frequent.

On coming into port, very little repair will be needed, and the ship will be delayed but little in her money-earning occupation.

484. How is the cost of lubrication affected by the different rates of supply and by different qualities of the lubricant?

Undoubtedly, the direct cost of lubrication will be higher, with ample supply of high-grade lubricants, but the indirect

advantages, in saving coal by reduction of friction and in reducing the repair bill and lost time to the smallest possible amount, will make that system probably most economical that supplies the best quality in ample, although not wasteful quantity.

485. What are the important qualities that a lubricant should possess?

(1.) Body.
(2.) Fluidity.
(3.) Freedom from gumming ingredients.
(4.) Freedom from acidity.
(5.) Stability under temperature changes.
(6.) Freedom from all foreign matter.

486. What is understood by the term "body of a lubricant?"

The "body of a lubricant" indicates a certain consistency or substance, that prevents it from being squeezed out easily from between the moving bodies. The particles of the lubricant should adhere as firmly as possible to the moving bodies thus securing effective separation and prevention of direct contact.

The body of the lubricant will also prevent a too rapid running-off of the lubricant.

487. What is understood by the term "fluidity of the lubricant?"

The fluidity of a lubricant refers to a certain lack of cohesion between the different particles of the substance, that reduces the fluid friction to a minimum. As this fluid friction should be mainly the resistance that must be overcome, fluidity, so far as it does not oppose "body," is a desirable quality. Excessive fluidity lets the lubricant run off too quickly, thus leading to waste.

488. Why should lubricants be free from gumming ingredients?

A lubricant that gums loses its fluidity easily, collects dust and grit, and thus increases friction and wear and tear generally.

489. Why should lubricants be free from acidity?

A lubricant that holds free acid would attack the bearing surface, destroy its smoothness, increase friction and lead to frequent and costly repairs.

490. Why should lubricants possess stability under temperature changes?

Lubricants should retain their good qualities, even when used under high temperatures, as in steam cylinders or valve chests, or when used under low temperatures, as in ice machines or exposed winches and windlasses. They should not evaporate nor be decomposed by the heat, nor congeal by the cold, and should retain their normal body and fluidity as much as possible.

491. Why should the lubricant be free from all foreign matter?

Foreign matter will increase the friction, and clog the feeding tubes, thus leading to dangerous accidents. Water in the lubricant decreases the amount that the wick can draw, where wick feeding is employed.

492 What determines mainly the choice of a lubricant for a given purpose?

(1.) Price.
(2.) Pressure per square inch of surface.
(3.) Velocity of one body over the other.
(4.) Temperature.

For heavy pressures, the lubricant should have a good dea of body, while for lighter pressures this is not so important.

For high speed, the lubricant should, preferably, posses good fluidity, while, for slow speed, less fluidity is desirable t prevent useless waste.

For low temperatures, light mineral oils are preferable a lubricants, while for high temperatures heavy mineral oils ar employed.

For marine engines, generally, two kinds of lubricants ar selected, one for internal, or cylinder lubrication, the other fo external, or engine lubrication. From these two qualitie many engineers produce intermediate grades by mixing, a they consider them best suited to the different and varyin requirements in the engine.

493. How are lubricants classified?

Lubricants may be classified as

(1.) Solid.

(2.) Semi-liquid.

(3.) Liquid.

494. What are the characteristics of solid lubricants?

The solid lubricants are generally graphite or soapston They are well adapted to bearings, with heavy pressure an slow speed, where they have been found very lasting an economical.

Graphite, being unaffected by even the highest temperature is considered by some engineers an excellent lubricant f steam cylinders and valve chests, and is either fed continual into the cylinder or applied only by occasional rubbing upo the cylinder walls, valve-seats and faces.

For surface condensing engines some engineers object to th use of graphite in the cylinders, as being liable to reduce th cooling efficiency of the condenser by coating the tubes.

Soapstone is sometimes used mixed with oils, for a lubricant, on journals that are liable to run hot.

Sulphur powder is also mixed with oil for the lubrication of hot bearings.

495. What are the characteristics of semi-liquid lubricants?

Semi-liquid lubricants are employed in the form of grease and tallow. They are well adapted for heavy pressures under slow speed, but not for high speed, as their internal or fluid friction is considerable.

One great advantage of semi-liquid lubricants is their durability and lasting quality. They do not run all over the engine, which fact enables the engineers to keep the machinery in very neat and clean condition, and, as many think, offsets the disadvantage of greater friction.

496. What are the characteristics of liquid lubricants?

Liquid lubricants are the most commonly employed for all purposes of either internal or external lubrication. They represent, in some forms, the highest quality of lubricants, having considerable body, with good fluidity and small internal friction. Their fluidity, however, may lead to large and even wasteful consumption; and, by being easily spattered over all parts of the engine, they do not allow of as great cleanliness as may be had with the semi-liquid lubricants.

497. What other classification of lubricants may be made?

Lubricants may be classified according to their origin, as:

(1.) Mineral.
(2.) Animal.
(3.) Vegetable.

498. What are the characteristics of mineral lubricants?

Mineral lubricants may be used directly in powdered form,

like graphite or soapstone, or they may be gained in t semi-liquid form of grease, or the liquid form of oil, by t distillation of petroleum.

The liquid mineral oils are the most important lubricants, a since, with modern methods of manufacture, their price relatively low, their use is rapidly becoming universal. Th retain their qualities well in the air, and, if pure, do not gu or dry up. They are characterized and judged by col specific gravity, body, flashing point, burning point, cold-t point, and by the amount of suspended matter.

The color, for the different grades, varies from light yell to dark brown.

The specific gravity ranges from 88 to 92, and the heav oils are generally, also, the thicker and less fluid. The body generally higher with the thicker oils, comparing those of t same color.

A compromise between body and fluidity must be made f the best and most economical result, so that good adhesi and slow running-off is combined with moderate internal fr tion.

For cylinder oils the body should be the more pronounc quality, as fluidity is increased by elevation of temperature.

The flashing point is the temperature at which the oil gi off inflammable vapors, while the burning point is the te perature at which the oil itself takes fire. Particularly cylinder lubricants these points are of great importance, a an oil should always be employed that has the flashing po considerably above the temperature of the steam.

The cold-test point is the temperature at which any giv grade of oil will either freeze or become cloudy. The amo of suspended matter is, with the light oil, directly seen or, the darker oils, determined by mixing and shaking with relatively large quantity of gasoline.

499. What are the characteristics of the animal oils?

The animal oils are gained in semi-liquid form, as tallow, or in liquid form, as sperm, whale, fish, lard and Neat's foot oils, by boiling or melting from the raw animal parts. Animal oils are decomposed gradually by the air, and turn rancid under development of acid. As some of them are treated by acids in the process of manufacture, they are liable to have an acid reaction, and are then undesirable.

Tallow is used for slow running shafts and moderate pressures, also for internal lubrication of engines with injection condensation. It is also frequently applied to hot bearings. It should be free from all acid. Beef-tallow is considered the most desirable, and should be hard, granular, and of uniformly white color. Good tallow should be clear upon melting, without the rancid, disagreeable smell produced by mutton or other tallows. Mutton tallow and horse tallow, or horse grease, are of inferior quality, but are used with advantage by many engineers.

Sperm oil is one of the best lubricating oils in use; it does not become rancid; does not dry up; has good body, and is fluid, with little internal friction. It is employed for rapid-running parts, where a high-grade oil is desirable, without much regard to price.

Whale oil is used frequently for external, or engine, lubrication, where a good lubricating oil at a moderate price is desired.

Fish oil is also employed by some engineers with good advantage for external lubrication.

Lard oil is used more generally for mixing with other oils than alone.

Neat's foot oil, on account of high price, is used in small quantities only for improvement of oils of poorer quality.

500. What are the characteristics of vegetable oils?

The vegetable lubricating oils are gradually decomposed by the oxidizing influence of the atmosphere and dry up; they are also inclined to gum.

The process of manufacturing consists in pressing them from the raw material, and cleaning out the cloudy, suspended fibres by treatment with acids. The color of the refined oil is from water white to light yellow. Under heat they evapo

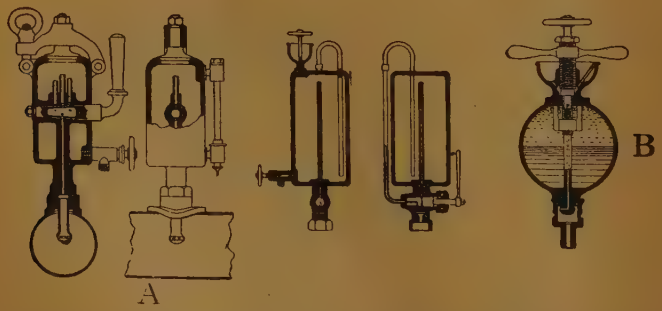


FIG. 177.—Sectional Views of Several Types of Internal, or Cylinder, Lubricators and I permeators. At A is shown the main steam pipe to which the oil cup is attached; B, a type of oiler in which the oil is forced out by a constantly rising water level.

rate easily, and are, therefore, employed only for externa or engine, lubrication.

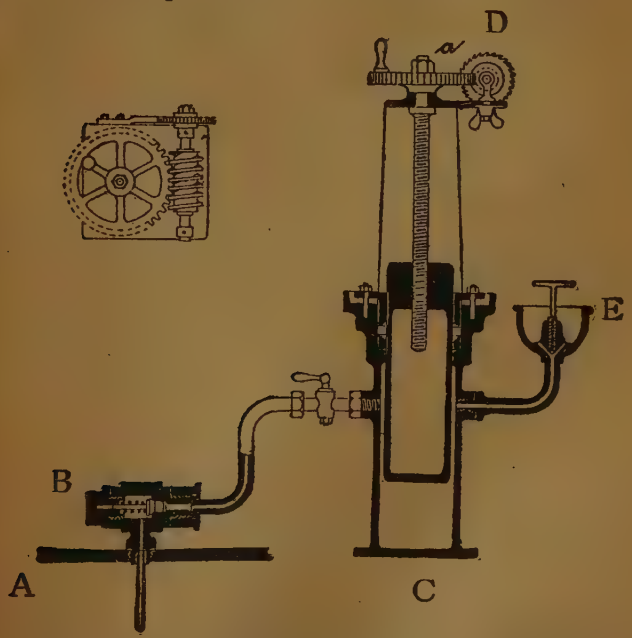
Rape oil should be used, after being well separated fro the suspended matter. It becomes rancid easily, gums slightl and should, therefore, be kept from heat and dust. It has goo lubricating qualities, although used less often than the anim oils.

Olive oil possesses still better lubricating qualities than ra oil. It neither dries up nor gums, but generally contains aci Its high cost involves that it is frequently adulterated wi cheaper oils.

Cottonseed oil dries up less easily than others, and is co

equently used sometimes as an admixture to olive oil. Certain rades frequently show an acid reaction, and are undesirable or lubricating purposes.

Linseed oil dries up easily, and is hence undesirable for ubrication; it is often found as an adulterant in other oils on ccount of its cheapness.



IG. 178.—A Type of Force-pump Lubricator. At A is shown the main steam pipe; at B, the check valve at the end of oil pipe with stop cock; C is the oil space in the pump, in which slides a plunger on a screw spindle; D is a worm-wheel screw and ratchet, plan of which is shown in diagram at the left; E is the oil-filling cup. (Section 505.)

01. Are the lubricating oils used always alone?

No; mixtures of different oils are very frequently employed ith advantage.

For cylinder lubrication mineral oil, as the main part, is ften mixed with sperm, whale or lard oil, this being consid-

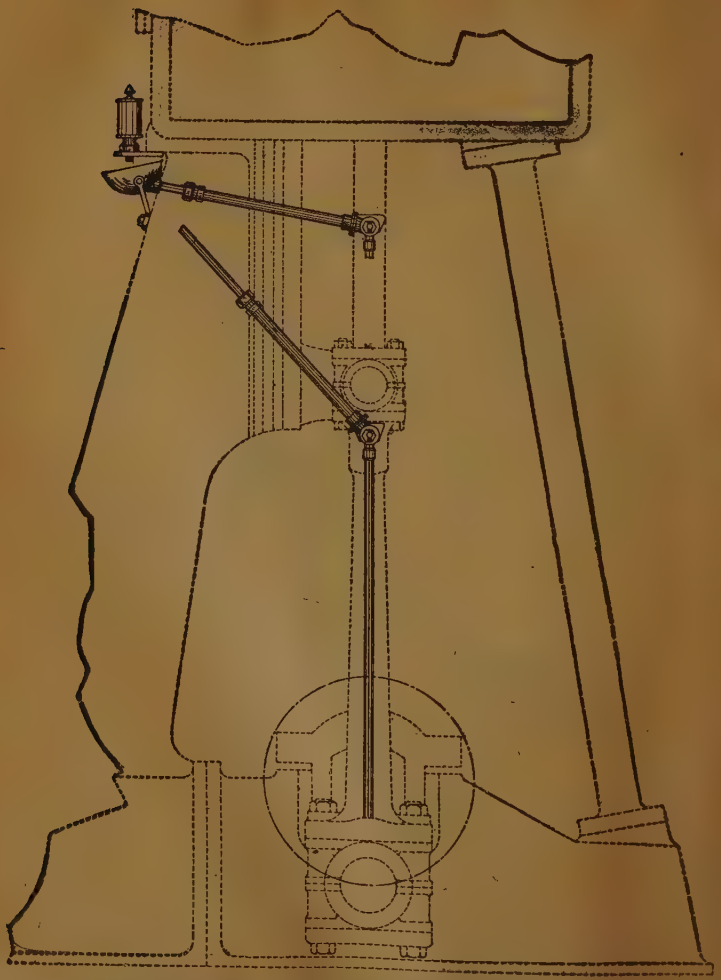


FIG. 179.—Telescopic Crank-pin Oiler. This arrangement enables the oiling of t moving parts of the engine, by means of swing-jointed telescopic pipes leadi from a single oil cup, as shown. The use of such a device enables the parts to oiled without stopping the engine or endangering the attendants. (Sections and 512.)

ered by manufacturers and engineers as to the best compromise between price, body and fluidity or rate of consumption.

Sometimes such mixtures are frankly marked as mixtures, while often they are sold with fraudulent intent. Engineers, therefore, should exercise caution in the purchase of lubricating oils.

502. What tests are employed to determine the quality of lubricating oils?

The tests may be chemical or mechanical. The chemical tests are made in the laboratories, as are also certain mechanical tests, requiring special instruments, such as the flashing, burning and cold tests. Simpler tests may be made for specific gravity by the hydrometer.

The clearness of the oil may be determined by taking a sample from a barrel that has been well rolled and shaken. The glass used should be clear and very transparent, and the oil, if very cold, should be slightly warmed in it. After this the oil should show perfectly clear and without suspended matter.

A test for acidity may be made by mixing a small quantity of oil with warm water or alcohol, and testing with blue litmus paper, which will become red if any free acid is present.

To determine whether the oil is rancid a few drops may be rubbed between the hands, when the smell will indicate this quality, if present.

To determine the purity of the oil a small quantity may be shaken in a bottle with a quick jerking motion to produce air bubbles. If the oil is pure, the bubbles will soon burst and disappear, but if it is mixed with other oils the bubbles will rise to the surface and collect, until at last they form a regular rosary around the side of the bottle.

If several oils are submitted for comparison, a general indication of quality may be gained by dropping a sample of each oil upon an inclined sheet-iron plate. The oil which

takes the longest run and remains liquid the longest is probably the most desirable.

The purity of tallow may be judged by boiling with six parts of water. If cooled again, a sediment will reveal impurities.

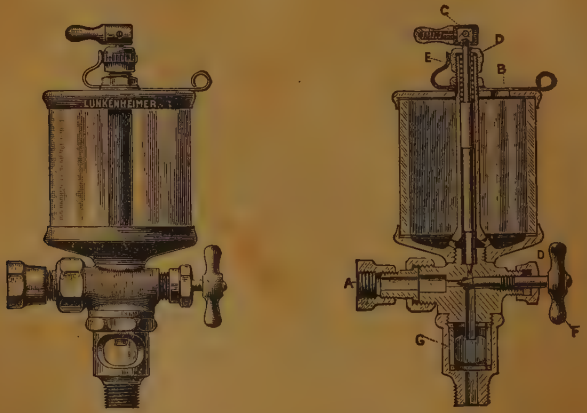


FIG. 180.—Exterior View and Section of a Common Form of Sight Feed Oil Cup, with regulating valve and connection for oil-force pump. A is a union for connecting oil supply pipe; B, slide filter; C, cam lever; D, caps, one retaining spring on stem of needle valve; the other retaining packing on valve stem of F; E, clip springs bearing on screw cap; F, valve for shutting off oil supply; G, section of glass tubing, to enable the oil drop to be seen and counted.

503. How are the lubricants applied to the bearing surface?

The lubricants must be applied in a continuous stream to the bearing surface to secure uniformity of lubrication. This supply must be capable of regulation, in order to feed just enough lubricating material without waste.

To economize in the labor of attendance by the engineers oil cups are supplied that are filled with a large quantity of oil, and from them the bearing is supplied automatically with any number of drops per minute that may be found necessary for efficient lubrication.

504. How is the automatic supply provided by the oil cup ?

The automatic supply from the cup to the bearing is effected by

(1.) Difference of gravity between oil and water.
(2.) Pressure through screwing down of a piston or cap.
(3.) Pressure of springs.
(4.) Throttling of an orifice by a valve or stopper.
(5.) Suction through wicks.

505. What methods and devices are employed for internal, or cylinder, lubrication ?

The internal, or cylinder, lubrication is effected by displacing the oil, drop by drop, through condensed water, or by forcing it into the steam pipe, or valve chest, by a force pump, actuated by a screw and ratchet wheel from the main engine.

The first apparatus takes steam from the steam pipe and condenses it in a coil of copper piping or a bulb-shaped vessel.

The water enters at the bottom of the oil cup and forces the oil out at the top into the steam pipe. Gauges are provided that show the amount of water and oil in the cup, and also the drops of oil that pass into the steam.

Valves are arranged for regulating the flow, for connecting and disconnecting to the steam pipe and for draining and filling of the oil cups. The advantage of this apparatus is that it has no movable parts, while objections are raised that it may clog up and stop feeding; also, that the coil type may retain water, upon laying-up, and, in winter time, burst the coil, or the apparatus, by freezing. The apparatus continues feeding even when the engine stops, and may thus waste considerable oil if not regulated.

The force-pump type of cylinder lubricator is constructed like a single-acting force-pump, with a plunger screwed down by a spindle. On the top of the apparatus a ratchet lever receives

motion from some moving parts of the main engine, such as the air pump beam or a valve stem, then transmitting its reciprocations to a continuously-revolving ratchet wheel, which in turn, acts through a screw upon a worm wheel on the main spindle.

The motion is thus transmitted to the plunger with a large reduction in speed, forcing the oil very slowly, but powerfully into the steam pipe, or valve chest.

The certainty of action and stopping of the feed, when the engine stops, are among the advantages of this apparatus, while

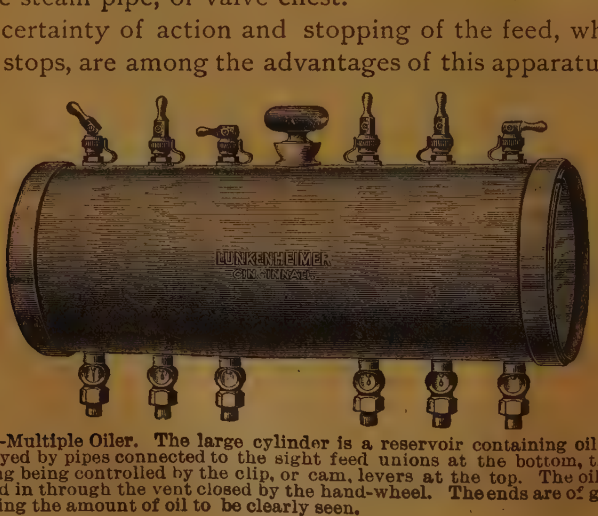


FIG. 181.—**Multiple Oiler. The large cylinder is a reservoir containing oil, which is conveyed by pipes connected to the sight feed unions at the bottom, the rate of feeding being controlled by the clip, or cam, levers at the top. The oil supply is poured in through the vent closed by the hand-wheel. The ends are of glass, thus allowing the amount of oil to be clearly seen.**

the moving parts, gears and stuffing-box are disadvantages that increase the labor of the engineers.

506. What methods and devices are employed for external, or engine, lubrication?

For external, or engine, lubrication pressure by springs is employed for grease cups, while other cups for semi-liquid lubricants have screw-down caps that occasionally receive an additional turn by the attendant, thus keeping up the pressure and continuity of supply to the bearing.

Tallow cups sometimes have a large hole in the bottom, so that the tallow rests directly upon the journal and is gradually carried off by it.

Regulation of the oil supply to the bearing, by throttling the opening, is used in marine engines, most frequently in the form of large vessels, with a number of outlets to different bearing surfaces. The cups have an orifice in the bottom

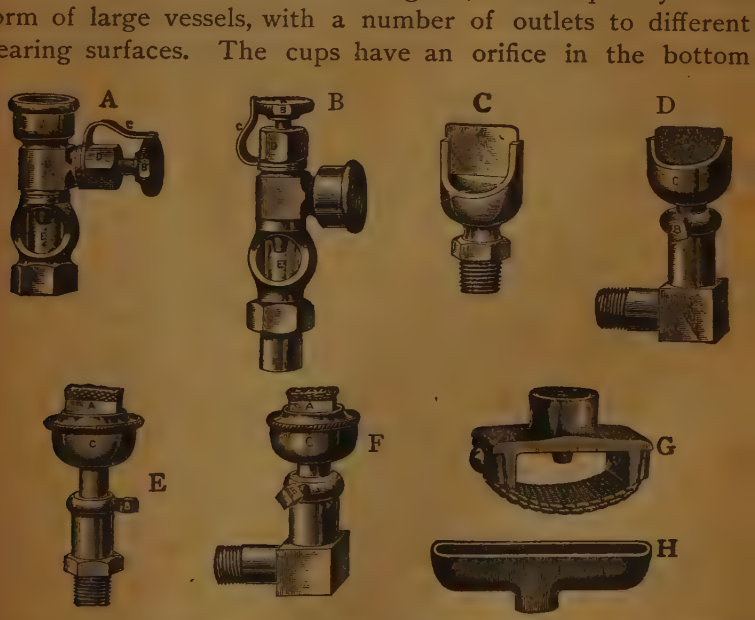


FIG. 182.—Parts and Details of Oil Cups and Wipers. A is an oil regulating valve with sight feed; B, angle oil regulating valve with sight feed; C, wiper cup; D, angle wiper cup; E, wiper; F, angle wiper; G, wiper; H, drip cup.

that is partially closed by a stem, or valve, adjustable in the upper cover or side of the cup.

To be sure of the action of this cup, it is nearly always provided with sights, consisting of glass tubes, for allowing the number of drops of oil per minute to be seen and counted.

On stopping the engine, the stems or valves are closed down upon the openings.

The most frequently-used lubricator is the suction wick type. The cup of this lubricator is provided with one or more small tubes, tapped or driven oil-tight into the bottom of the cup, and reaching up to near the top.

To lift the oil automatically over the edge of this tube, a suction wick, acting like a siphon, is placed in the tube, at one end, while the other end dips into the oil in the cup. The end in the tube should reach well down below the level of the oil, in order to secure good suction and rising of the oil in the wick. Around the wick is wound a wire that holds the wick in place by its stiffness.

The wick cups are employed individually on each bearing, or are arranged in a group of several together, in one large cup with outlets and pipes to the different bearings. Upon stopping of the engine the wicks are removed from the tubes to prevent waste of the lubricant.

507. What systems of distribution are employed in the external, or engine, lubrication?

Mainly two systems of lubrication are employed:

(1.) Supply at each individual bearing.

(2.) Supply at central cups, which serve several bearings by tubing.

508. What are the characteristics of the individual cup system?

The individual bearing supply system has great certainty of action, as the attendants, if faithful, will immediately detect any trouble in the lubrication, such as heating of the bearing, etc. The short and direct passage from the cup to the bearing will tend to avoid clogging-up, or, in any case, allow a quick and easy removal of the obstruction.

This system, however, requires considerably more labor and attention by the engineers; is frequently insufficient for bear

ings; is hard of access, and exposes the oilers more to the danger of being caught in the moving machinery parts. For some parts, like crank pins and eccentric sheaves, it is even impracticable as being too difficult of access. As the height of the oil level above the bearing is small, only a little pressure can be exerted upon the rate of flow.

509. What are the characteristics of the central cup supply system?

The central cup system places large cups in position convenient of access for filling by the engineers, and leads the oil to the bearing by small tubing, which may be conveniently arranged. By a careful arrangement of relatively wide tubing, direct leads and easy, long bends, a very good lubrication may be secured, even for bearings relatively inaccessible. The labor of filling is also greatly reduced and safety for the men correspondingly increased.

The pipes, if of some length, offer certain dangers of obstruction by foreign matter, and of suspending lubrication to parts which, perhaps, may not be detected before heating of the bearing has commenced and damage is done.

The central cup also needs sights to each feeding pipe, showing the attendant, distinctly and clearly, that each feeding pipe receives and delivers its proportionate amount of oil.

510. What system of lubrication is most often employed?

Modern marine practice employs a combination of the two systems, generally providing one or two central cups for each cylinder, feeding mainly to the moving parts and the crosshead, while the main crankshaft bearings and the reversing gear are frequently lubricated from individual cups.

Stuffing-boxes are sometimes supplied by individual cups.

placed high to obtain sufficient head and pressure upon the feed through the pipes.

A special form of individual cup is the centrifugal crank pin oiler, which forces oil to the bearing in the lower position of the crank.

511. How are oil cups constructed?

Oil cups may be parts of the bearings, as frequently found on the main bearings, or they may be independent, constructed generally of cast brass, sheet brass or copper, brazed or soldered.

For large central cups, lengths of tubing of large diameter are employed, sometimes with glass ends, to allow the quantity of contained oil to be seen.

All cups should have a tight-fitting cover, to prevent dust and impurities from entering the oil and getting into the bearing.

512. How is the piping from the central cups arranged?

The piping from the central cups is generally of copper or brass tubing, varying from one-eighth inch to as much as one-half inch diameter. The connection to the sight feed nipples, or to the box itself, is made by brazing or unions.

The tubes are generally bent with long, easy sweeps to prevent all possibility of clogging, or jamming, and they generally allow the oil to drip directly upon the bearing surface or otherwise into a cup, as used on the moving parts.

The receiving cups are securely fastened to the moving parts in such positions that they will catch the dripping oil. They are often fitted with wipers that touch the end of the feed pipe and scrape off the drops of oil.

For the crank pin and the eccentrics tubes again lead from the receiving cups to the bearing brass.

A special form of tubing to the movable parts is the telescopic oiler. It consists of two concentrically sliding tubes

one of which is connected to a stationary, oscillating oil cup, which receives the oil in drops from above, while the other tube is connected to the upper connecting rod end with a form of plug-cock joint. A stuffing-box keeps the sliding connection between the two pipes tight, and prevents loss of oil.

513. How is the lubrication affected by the position of the oil entrance?

The lubrication may vary considerably in its efficiency, according to the distribution of the oil in the bearing, as influenced by the position of the oil entrance. If the oil runs through the bearing, without touching all surfaces equally, it cannot separate the bodies and substitute fluid friction for the solid friction.

For the purpose of distributing the oil all over the bearing surface, grooves, generally curved, are cut into the brass, starting from the oil hole. Engineers often exercise their own judgment in the style of oil grooves that they find efficient.

The strips and blocks of anti-friction metal, frequently fitted in the bearing brasses, offer excellent occasion for good distribution of the lubricant, but may lead also to great waste by letting the oil run out too quickly.

514. What provision is made in marine engines for retaining and saving the lubricant?

Oil-drips under and around the different bearings, of sheet brass or copper, catch the oil and can be emptied through drain pipes and cocks. The oil-drips of the slipper guides serve also for additional lubrication, while a wiper on the bottom of the slipper dips into the oil and drags it over the guide-bearing surface.

If the oil is considered suitable for being used again, it is filtered and cleaned from impurities. The same oil should not

however, be used many times, as small abraded particles of the metal will at last introduce undesirable qualities.

The economy exercised by engineers varies considerably. In engines of 500 to 2,000 indicated horse-power, engineers use from one to eight gallons of oil per day for engine lubrication, while from one-half to four gallons of oil per day are used for cylinder lubrication. A great deal depends upon the number of the auxiliaries, the quality of the oil and the watchfulness of the attendants.

CHAPTER TWENTY-TWO.

PACKING AND PACKING MATERIALS.

515. What is the purpose of packing?

Packing connects together the individual pieces of boilers and engines, ensuring the tightness necessary for the efficient performance of the machine as a whole.

For ease and readiness of manufacture a machine is built up of many pieces, which are jointed together by rivets, bolts, and screws. Thus the boiler sheets are jointed together into one steam-tight vessel, or the cylinders and their valve-chests may be held together steam-tight by bolts or screws. To secure this steam-tightness, more or less packing is required, in order so completely to fill up the interstices between any two parts that the contents of the vessel cannot escape through it.

516. How are the faces of the connected parts prepared for packing?

The faces of the connected parts, if prepared at all, receive rough hand dressing, or a more or less perfect machine tool dressing.

517. In what places is it customary to make only rough preparation of the faces for packing?

In the boilers, particularly, there are numerous cases where repair patches, manholes, valve flanges, etc., are jointed to the boiler shell with little or no preparation of the faces. A thick paste of red lead or iron rust cement, which hardens readily, fills up the interstices for complete tightness.

The seams of the boiler sheets may be considered packed by the caulking, which employs the malleability of the mate-

rial of the sheets, to prevent interstices by complete contact, at least along the caulking edge.

Where several pieces or sheets are jointed together at corners in more or less inaccessible places, packing in form of stop washers is sometimes resorted to, in order to secure better tightness than mere caulking could produce.

518. In what places is it customary to prepare the connecting faces for packing by the use of machine tools?

The preparation of packing faces on boilers for manhole covers is frequently made by machining; the flanged edges of manhole openings or their stiffening rings being thus prepared.

On the engine and the auxiliaries all joints are machined, for since they must be remade very frequently the higher the perfection of finish of the face, the less packing is needed, and the easier it is to keep the joint tight.

In some cases the finish of the joint is carried to such perfection, in the last stages even by hand scraping, that virtually no packing at all is required, and a complete metallic joint is made.

Slide valves and pistons and piston rings slide on their faces with such scraped joints, requiring no packing except a thin film of oil or condensed water between them to establish a practically complete tightness.

For very high steam pressure some engineers require that the pipe flanges be scraped and finished so nicely that nothing but a thin wash of red lead is needed between them.

519. What special preparations are made in the faces of the joints to prevent blowing out of the packing material?

The packing material is held between the faces of the joints

by the friction produced by the clamping pressure of the two parts, one against the other.

With high pressure this friction may not be sufficient to resist the internal pressure exercised against the thin edge of the packing. Retaining rims, inside or outside, around the opening, or male and female projections on the face of the flange, are, therefore, provided with high pressure, to relieve and remove the packing from the influence of the inside pressure.

520. How does the retained fluid affect the packing?

The packing is materially affected by the retained fluid, according to its temperature, density and chemical reaction.

The packings may be classified from this point of view into packings for

(1.) Steam.
(2.) Water.
(3.) Air, ammonia and oil.

521. What characteristics have the steam packings?

Steam packings, particularly for higher pressures and temperatures, should be as nearly incombustible as possible; they should not be decomposed or easily burned on to the faces of the joint.

On this account metallic packings are chiefly used for this purpose, and next in desirability are the fibrous packings, made from mineral substances like asbestos.

For low pressure or exhaust steam, other fibrous, or rubber, packings are cautiously used with advantage by engineers.

Around condensers and air pumps the packings should possess durability against the effects of mineral oil in steam or water.

522. What are the characteristics of the water packings?

Water packings may be metallic as well as fibrous. The

should, however, be of such material as to have no galvanic reaction upon the material of the pipes or machines, as sometimes experienced with copper rings.

They should not be decomposed or rotted by soaking, but should retain their elasticity, or softness, even under frequent making or breaking of the joint.

523. What are the characteristics of air, ammonia and oil packings?

The requirements for these purposes are limited, and the regular steam and water packings generally can be applied to these needs. The air pipes of forced ash-pit, or induced draft systems require some packing of fibrous, or rubber, materia for cold-air piping, and, of asbestos or metallic material, for hot-air piping or ducts.

Ammonia piping may have metallic, rubber or fibrous packing, according to the judgment of the engineer.

The main requirement in packing for oil piping is that it should not be dissolved, or decomposed, by oil, as are some of the soft rubber materials used for packing.

524. What other classification of packings may be made?

Packings may also be classified as those for

(1.) Stationary parts.

(2.) Moving parts.

525. What are the characteristics of the packings for stationary parts?

The packings for stationary parts are generally applied in form of sheets, thin and well spread out between flat faces or flanges of valves, cylinders, valve chests, etc. Occasionally engineers prefer to use a round metal, or fibrous, ring in a recess, instead of a flat sheet, as it is more easily made and kept tight, while bearing only on a narrow line, or ridge, all around the opening.

The choice of the packing is greatly influenced by the consideration of whether the joint is to be broken often, or will remain comparatively undisturbed for a longer period.

In the latter case materials may be employed that cannot be used over again, such as red lead or iron-rust cement, with or without fibrous gaskets, while, in the first case, quickness of making and preservation of the packing for continued use will be of importance.

526. What are the characteristics of the packings for movable parts?

The packings for movable parts are generally arranged in coils of several thicknesses to gain depth in the direction of the motion, or in the longitudinal axis, like the coils in the stuffing-boxes of piston rods, valve stems, condenser tubes, or in the packing of air pump pistons.

Packings for movable parts should be employed in good depth, with relatively slight pressure upon them, to retain elasticity and secure good durability and long life with little attendance and adjustment.

The renewing of stuffing-box or piston packing is generally a troublesome experience, attended with great expenditure of time and labor, like that of the condenser tubes, where the water chests must be removed, in order to get at the stuffing-boxes, or that of the air pump piston, where the top covers, valves and moving parts must be removed for access to the interior.

Oils, red leads and other substances that harden or bake should not be applied to packing for movable parts; also the packings themselves should be of substances that do not burn. Softness, pliability and elasticity should be their chief properties, and these should be retained as long as possible.

527. How is the packing applied?

The methods of applying the packing vary greatly, according to material, position, finish of faces of joint, nature and duty of part in need of packing. It is expedient to apply the hand-made packings in a heavier layer than the more uniform commercial packings. On rough surfaces more packing material is needed than on smooth or finished surfaces. Stationary parts, with a higher clamping pressure, need much less packing than movable parts, where the packing is compressed comparatively lightly.

528. How is the pressure exerted upon the packing?

The pressure upon the packing is generally exerted by bolts or nuts or tap screws.

For stationary parts the packing is clamped between stiff flanges which, with the numerous bolts, exert a very heavy pressure upon the packing. The bolts should be spaced closer together with light flanges than with heavy flanges, as otherwise a slight bulging of the flange between the bolts may take place, leading to leakage and final tearing and blowing-out of the packing material.

For moving parts the packing is forced into a special recess of the stuffing-box or piston by a gland or follower ring. As the danger of blowing-out is practically removed in these places, the area under pressure being generally much smaller than with stationary parts, and, as the desired elasticity of the packing makes a low clamping pressure advisable, fewer bolts are required.

529. What kind of packing is used for stationary parts?

The packings used for stationary parts may be divided into two classes: those that cannot be used again, such as iron-rust cement, red lead, with or without chopped hemp, and graphite: and those that can be more or less frequently used

again, such as the metallic gaskets, asbestos, pure rubber, mixed rubber and canvas, canvas or paper soaked in linseed oil, or applied in connection with red lead or graphite.

530. What kind of packing is used for moving parts?

The packing used for moving parts is generally employed in round or square rings or strands of soft metal, of asbestos, of rubber, of combinations, or of hemp made up into braids.

The packings, particularly the soft ones, are sometimes soaked with tallow, or graphite powder is rubbed into them to increase their durability and resistance to wear.

531. How are iron-rust cement, red lead and graphite employed as packing?

Iron-rust cement is applied to cracks, patches and repairs of permanent character in general, where the interstices must be filled by a body that becomes firmly solid and iron-like in nature. It is made up from fine iron filings into a cement or paste by treatment with acid. This turns the metallic iron into iron rust, baking the particles together.

Red lead is made up from the powder by mixing thoroughly with linseed oil, until it is of the consistency of paste.

It is used for the largest number of joints not too frequently broken, where the hardening of the red lead by the drying of the oil is of advantage for permanent tightness in the joints.

A thin wash of red lead, or only linseed oil, in connection with canvas or paper, is used with advantage for a large number of machinery joints, like cylinder covers, valve chest covers, etc., which require comparatively frequent lifting.

Graphite is applied, in conjunction with metallic, asbestos, rubber and fibrous packings, as powder or made up with a little oil or tallow to a paste. It is excellent for all joints that are frequently broken; prevents burning of the packing to the

faces, and effects a saving of material by keeping the gaskets in good condition for renewed employment.

532. How is metallic packing employed?

Metallic packing is generally made from the soft metals, which, under pressure, yield and shape themselves to the bearing surface. It is almost universally employed, and proves excellent for high steam pressure, where fibrous packing would burn and last but a very short time. The elasticity of metallic packing is, however, considerably less than that of the fibrous packing, and this is a certain disadvantage, particularly in stuffing-boxes. To overcome this lack of elasticity, certain constructions of metallic stuffing-boxes employ springs, which tend to prevent gripping of the packing on the rods. The greater complication of this arrangement is objected to by many engineers, and the simple, more rigid arrangement preferred.

Copper, lead, Babbitt metal and similar compositions of soft nature are employed with advantage in form of rings, sheets, stuffing-box coils, etc. Copper is employed in rings of round, or triangular, sections, or in corrugated discs for packing on flanged boiler valves, manholes, pipe flanges or engine flanges. It is very durable and lasting, but, with iron flanges or faces, it sets up galvanic action in some liquids, thus quickly destroying the smoothness of the faces.

The lead or Babbitt metallic packings are used in sheets for flanges, or in split rings for stuffing-boxes. Their melting point should be considered for high pressure steam. Babbitt metal may be mixed so as to resist very effectively any temperatures in use.

533. How is asbestos packing employed?

Asbestos packing is made in shape of sheets, round or square strands, wicks, etc., from the fibrous raw mineral material. It

has the valuable quality of being incombustible and imperishable, and is thus eminently adapted to all high pressure pipe and machinery joints around boilers and engines. It ranks with metallic packings in this particular. One great advantage is its softness, fibrous nature and comparative elasticity, while it is, on the other hand, not nearly as durable as metallic packing, and, therefore, more expensive. Some engineers employ asbestos packing, together with metallic packing, in stuffing-boxes, thus combining the softness and elasticity of the asbestos with durability of the metallic packing.

534. How is rubber packing employed?

Rubber packing is the most frequently employed material. Its great elasticity, comparative strength and toughness, tightness and moderate price make it an excellent packing for all water service, joints around pumps, pipes, manifolds and valves. Numerous engineers prefer some one of the particular makes of this packing for low pressure and exhaust steam joints.

Rubber packing is made in all sizes of sheets, gaskets, round and square strands, washers, etc., generally with a body of canvas in one or more layers, that increase the strength and resistance against blowing-out.

Graphite, rubbed on the faces of rubber packings, effectively prevents burning-on, thus allowing the gaskets to be used over.

535. How are canvas, paper or hemp packings employed?

Canvas and paper packings are employed generally only temporarily, where lack of the higher grade obliges the engineer to use a substitute. They are used soaked in oil and coated with graphite, grease or red lead in order to give more body and tightness.

Hemp packing was formerly made by the engineers from the raw material into braids of varying thickness, shapes and length. The modern commercial packings, however, made up and ready for use, save so much time and labor, and prove in the end so much cheaper, that the practice has practically died out, being employed only in emergencies and special cases.

CHAPTER TWENTY-THREE.

CARE AND OVERHAULING IN PORT.

536. What precautions are taken with the boiler in emptying its water?

The boiler containing water is allowed to cool very gradually, keeping dampers and fire doors well closed, to prevent any cold air from touching the inside parts, and from starting leakage in the seams by unequal contraction.

With the fires all drawn and the steam pressure gone, the well-cooled water is pumped out slowly or, after starting the lower man and hand holes, is allowed to run gradually into the bilge of the ship.

537. How is it customary to fill the vacuum, caused by pumping the water from the boiler?

Air is admitted to the boiler automatically, through a special valve, or by loosening one of the upper manholes, or by slightly lifting one of the safety valves with the hand-lifting arrangement.

538. What work is done on the boiler after the water is emptied from it?

The work done on the boiler consists largely in:

(1.) Cleaning, outside and inside.

(2.) Inspecting and repairing.

539. To what parts does the outside cleaning of the boiler extend?

The outside cleaning extends to the outside shell, the furnaces, combustion chamber, the tubes, uptake, smoke-pipes and

funnel for fire-tube boilers; while, for water-tube boilers it extends to the casings, the furnace, the spaces around drums and tubes, the tubes, uptake and funnel.

540. What points receive special attention in the outside cleaning?

The corroding influence of the atmosphere is most strongly felt on the shell and water legs of fire-tube boilers; the casings and lower drums being most exposed in water-tube boilers. Particularly where the bilge water has touched these parts, or can touch them, they should be examined and cleaned from rust, ashes, dirt or grease, to make sure that no weakening has taken place. The lagging may have been burned or spoiled by water in certain places, which should be cleaned and newly lagged.

The furnace corrugations and recesses around the bridge or the spaces between the lower-tube end of water-tube boilers receive attention by freeing them from ashes, clinkers or tarry deposits, and by ascertaining beyond doubt that they are in a thoroughly efficient state of preservation.

The inside of fire tubes and the outside of water tubes are cleaned with wire brushes or scrapers, during which process any defective part will give occasion for discovery and replacing.

541. To what parts does the inside cleaning extend?

The inside cleaning extends to the surface of the shell, furnaces, water legs, combustion chambers, tubes and flues, and mud drums for fire-tube boilers; while, for water-tube boilers, it extends generally to drums and tubes.

542. What material is removed by inside cleaning of boilers?

The material removed by the inside cleaning is mostly scale

thrown down on the heating surface from the water while it is under the influence of heat.

543. Of what nature is this scale?

Scale in boilers may be of hard, rock-like nature; or of soft, greasy, or powdery nature, according to its chemical and mechanical composition or formation.

544. How does the scale get into the boiler water?

The scale, or the ingredients that form the scale, get into the boiler by the feed water.

545. How does the feed water receive the scale ingredients?

The feed water for jet-condensing plants is obtained from a different source from that of surface-condensing plants, therefore the scale formation is of a different nature for these two classes.

546. From what does scale formation originate in jet-condensing plants?

Scale formation in boilers of jet-condensing plants results from salts, which were contained in the hard feed water, as obtained from the hot well, when drawn in by the vacuum of the condenser.

547. What salts are most frequently found in the scale of the boiler?

The salts found in the scale of boilers and deposited from the hard, fresh feed water are generally various combinations of lime or magnesia.

548. From what does scale formation originate in surface-condensing plants?

Scale formation in boilers or surface-condensing plants results mainly from the sea-water that enters the boiler, as feed make-up, or through leakage of the condenser. Some of

the salts from the sea-water are, at boiling, thrown down upon the heating surfaces, where they adhere very firmly.

Another source of scale formation may be the oil used for cylinder lubrication, which is carried by the feed water into the boiler. It may form a kind of scum on the surface of the water, or combine with scale particles or impurities, and settle on the heating surface.

549. What effect has the scale upon the heat transmission of the heating surface?

Scale, not being a good heat-conducting substance, decreases the transmission of heat to the water considerably, even in thin layers, while with thick deposits of scale the heat transmission may stop altogether, leading to a dangerous over-heating of the heating surface, which may result in a complete collapse. With a large collection of scale the space between tubes or other parts of the boiler may be obstructed and the free circulation of the water and its cooling action seriously interfered with, leading to over-heating and damaging of the heating surface.

The deposit of combined oil and scale is more retarding on the heat transmission than the hard scale alone.

550. Does the scale react upon the metal of the heating surface?

The scale does not react directly upon the metal of the heating surface. A very thin coat of scale may be even advantageous for the preservation of the boiler metal by protecting it against corroding influences.

551. How is the inside of the boiler cleaned from scale?

The scale, being generally hard, is removed by scaling tools or chisels, while the softer deposits are scraped off, or washed down, with the stream of a hose.

On removing the scale, care should be exercised not to injure

the boiler material, while at the same time all recesses, furnace corrugations, tube tops, and other less easily accessible places, should be thoroughly cleaned.

552. What facilitates access to all the surfaces needing to be scaled?

The access to the surfaces of the boiler are greatly facilitated by a careful arrangement of the manholes and stays, as well as by leaving good space around tubes and combustion chamber. With good access the rapidity of the cleaning and scaling is greatly increased.

553. How is the scaling done in water-tube boilers?

The process of scaling in the drums of water-tube boilers is the same as in fire-tube boilers, but, for the tubes, special scrapers of watch spring steel or wire brushes are employed. These scrapers, or brushes, are drawn or pushed through the tubes with more or less ease and rapidity, according to the form of the tubes, as straight or curved. In double-tube boilers, the inner tubes must be removed for access to the larger ones.

554. Why is the boiler inspected after being cleaned?

After cleaning the boiler a careful inspection is made for defects, needing to be remedied, before it is placed again in service.

555. What defects are usually found in boilers after a period of service?

The defects usually found to develop during the period of service are:

(1.) Corrosion of the parts outside and inside.
(2.) Leaky or split tubes or stay bolts.
(3.) Leaky seams and rivets.
(4.) Leaky manhole covers, valve and pipe connections.

556. How does corrosion affect the parts of the boiler?

Corrosion may show itself upon the shell, the tubes, the combustion chamber, the furnaces, the drums or heads, stays or braces. It may extend over the whole surface, or may show only locally in the form of pitting.

557. What produces corrosion in boilers?

Corrosion on the outside is largely rusting under the influence of air and moisture.

The outside of the boilers may also be attacked quite severely by the bilge water, if they are not raised sufficiently from the bottom of the ship, while water that finds its way under the

FIG. 133.—Section of Boiler Plate at a Riveted Joint, showing the effects of corrosion of the metal. The normal surface of the plate is indicated by the dotted line across the opening of the corroded gap.

lagging, or covering, may, likewise, attack the sheets of the boiler or the casing.

The inside of the boiler is liable to be corroded by the influence of

(1.) Air.
(2.) Acids.
(3.) Galvanic action.

558. How does air corrode the boiler?

Air may be carried over by the feed water into the boiler, and, in connection with carbonic acid, may produce a severe corrosion, or rusting.

559. How do acids corrode the boiler?

Acids may be introduced by the feed water, or they may

form in the boiler from some of the salts held in the water. Acids will solve the metal directly, and, in large amounts, may inflict serious damage and wholesale destruction.

560. How does galvanic action corrode the boiler?

Galvanic action may set in between some of the bronze, brass or copper valve casings, or pipes, and the steel material of the boiler. If the water contains a slight amount of acid, the action may show itself very strongly, and frequently concentrate upon localities in so-called "pitting," changing the material in this pit to a soft, pasty combination of the steel with other chemical elements.

561. How are the tubes and stay bolts inspected?

Tubes and stay bolts give generally indication of defective condition while in service, and so the engineer will often know which tubes leak or are split and which stay bolts are broken, or leak around threads. Often a deposit and burning-on of the impurities of the water which has leaked out will show a defective tube, or stay, that can then be removed or marked for tightening.

562. How are the seams and rivets inspected?

The seams and rivets generally give indications while in service of leaks or looseness, except under the lagging, or covering, where they may evade detection for a while. Where doubt exists as to their tightness, the whole boiler should be exposed and carefully examined, for efficient caulking of seams and rivet-heads, replacing loose rivets by new ones or by screw bolts.

563. What attention is given to the manhole covers, and to the valve and pipe flange connections?

The manhole covers are refitted to their seats, if bent or

marked; the dogs are replaced, if necessary, and loose nuts o worn bolts are replaced by new ones.

The valve and pipe flanges are furnished with well-fitting washers or new bolts, as required.

564. How is the boiler again prepared for service?

The parts of the boiler that have been attacked by corrosion are given a wash with thin Portland cement; the holes produced by pitting being completely filled with cement.

To counteract the galvanic action upon the steel material o the boiler, zinc plates, or slabs, are fitted so as to be attacked and consumed by the galvanic action and thus save the stee parts.

565. How are the zinc slabs fitted?

The zinc slabs are frequently provided, in dimensions o about one-half square foot, one inch thick for every 25 to 3 indicated horse-power, and are well distributed throughout th boiler. They are often suspended from the stays, and car must be taken that the zinc, the supporting strap and the sta touch one another with a good, bright metallic contact to insur the permanency of the galvanic action.

566. What care must be taken in cleaning the boiler?

Care must be taken to remove from within the boiler a cleaning materials, pieces of wood, tools, etc., that have bee used in the work of cleaning and inspection.

A special survey must be made to see that all the opening from the pipes and valves are clear and free from obstruction All internal pipes, like dry pipes and internal feed pipes, shoul be well connected and thoroughly supported.

567. How are the manhole and handhole covers prepare and fitted?

The manhole and handhole covers get a thick coat of red lea

under and on the well-fitting packing ring of metal, asbestos, hemp or other packing material. In placing them in the opening, and drawing the bolts up through the dogs, care should be taken to keep the cover nicely central, and to tighten the bolts evenly, in order to obtain a uniform clamping pressure all around the opening on the packing material.

568. How are the water gauges prepared and fitted?

The water gauges should be inspected for clear openings by pushing a wire through the connections and then fitting them with gauge glasses. The rubber washers, used to tighten the glass, should be carefully fitted, to make sure that they do not come in front of the bore of the glass.

569. How are the cocks and valves fitted for service?

Cocks and valves should be reground, or tightened, to make sure that they do not leak, while still easily moved. They should be well cleaned and then fitted with packing between the flanges and in the stuffing-boxes. Hand-wheels and handles are well fitted, always ready for use.

The safety valves should have their weights or springs, with their lifting gear, inspected and put in good working condition.

570. How is the serviceable condition of the boiler and the fittings ascertained?

To ascertain the serviceable condition of the boiler a test by hydrostatic pressure is applied.

571. How is the test by hydrostatic pressure made?

The test by hydrostatic pressure is made by pumping the boiler full of water, until the test pressure is attained. The boiler is then inspected to discover possible change of form, or leakage from seams, rivets or fittings.

After a successful test the boiler is completely prepared for

service by placing lagging on the shell and pipes, filling the water space to the prescribed water line, and placing the furnace fittings.

572. What is done in filling the boiler with water?

The boiler is filled with water either from the dock by a hose through one of the upper manholes, or otherwise from the harbor water.

As it is desirable to obtain the cleanest and freshest water possible for the boiler, the supply from the dock will generally be preferable.

The supply of the harbor water is generally admitted by the bottom blow valve or cock, until the level in the boiler is the same as that of the water outside. If the boiler should not then be filled to its prescribed water level, the bottom blow is closed and the rest of the water supplied by pumping.

To allow the air to escape from the boiler, the safety valve and gauge cocks are lifted or left open.

573. How are the furnace fittings prepared for service?

After cleaning out the combustion chambers and furnaces the bridges are built up, or repaired, with fire bricks, the grate bearers and their supports fitted and the ash-pans put in place. The grate bars are placed upon the bearers, so that they are not too close together to allow for expansion under the heat of the fire, while, on the other hand, they should not be too far apart, and thus allow the coal to fall through the grate unburned.

The air valves in the hot draft arrangements are overhauled and the ash-pit doors are placed and fitted, so that they swing easily.

574. How is the funnel prepared for service?

The funnel has its cover removed and the stays adjusted, so that they support the funnel, and are still slack enough for

expansion of the funnel by the heat of the gases of combustion.

575. How should the boiler room be kept ready for service?

All parts of the boiler should be kept clean and painted where advantageous. All fittings should be operated occasionally, to make sure of their serviceable condition. The fire tools, wrenches and other implements should be in their supporting racks, ready for immediate use, and everything should be kept out of the fire rooms that does not belong there.

576. What precautions are taken with the engine when the ship comes into port?

The engine is cooled off very gradually, to prevent straining and damage by unequal contraction.

The cylinder and valve chest covers are lifted only slightly at first. The lubricators have the wicks removed or are closed down, and the oil drawn off into tanks. The guards and safety rails are taken down to facilitate the access to the engine and the auxiliaries.

577. What work is done around the cylinders?

The covers are removed, after the engine has cooled sufficiently, and the bore of the cylinder inspected for smoothness and wear. The piston follower ring is taken off, and the condition of the packing ring and the springs that force it out against the walls of the cylinder are ascertained. The nut that holds the piston on the rod is inspected, to ascertain whether it has remained screwed down hard and is securely locked in place.

Broken or worn bolts and nuts of the follower ring are replaced, and the springs are reset, so that a uniform pressure is exerted on the packing ring.

If liners are fitted they are inspected for preservation of the

packing at the outer end, while the tap screws at the inner end are carefully examined to see if they are loose or broken.

For large engines or tandem arrangements manholes are fitted that allow access to either end of the cylinder, without removing the piston.

578. What work is done around the valve chests ?

The valves are removed and the seats inspected for smoothness or wear.

Solid piston valves, if worn, may have to be replaced by new ones, while those fitted with packing rings must have the rings spread. Poppet valves are inspected for tightness on their seats, and the seats are examined, if loose. Since, with double-seated valves, it may happen that the distance between them is a little more, or less, than the distance between the faces of the seats, leakage may occur through either the upper or lower valve. An adjustment is made either in raising or lowering one of the seats, or in decreasing or increasing the length of the distance piece between the valves.

579. How are the cross-head and the connecting rod overhauled ?

The attention given to cross-head and connecting rod is mainly directed to taking up the slack in the bearing brasses.

In the latter part of the voyage the engine will have given indication of too much slack by severe pounding and knocking, and the engineers will generally know how much fitting is required.

If much wear has taken place, re-Babbitting may be required, where anti-friction metal is used.

580. How is the slipper guide overhauled ?

In the readjustment of the slipper guide care is taken to see that the faces of the guide remain exactly parallel to the centre line through the cylinder axis and the centre line of the

crankshaft. In larger repairs, where a cut has been taken off the face of the guide in the planer or milling machine, an accurate lining-up is employed to secure this parallel position. To meet the wear, either the guide may be brought toward the centre by shims or distance pieces, or the slipper may receive the shims, or have higher Babbitt slips or blocks fitted in the dovetailed recesses. The backing strips are then adjusted to the new position, or thickness, of the slipper. The cross-head guide in the horizontal river engines may require a more extensive overhauling, as the boat, after severe service, may change its shape considerably.

The distortion of the main axis, through the centre of the cylinder and the centre of the crankshaft, may be so great that a relining of the cylinder, as well as of the cross-head guide, may be necessary.

In beam engines the side pressure on the guide is generally so small that an adjustment of the slippers is seldom required. The result is then often due more to deformations of the gallows frame, and to correspondingly changed position of the walking beam.

581. How are the bearings in the cross-head and the connecting rod adjusted?

The bearings in the cross-head and in the ends of the connecting rod must be adjusted, not only to fit on their pins, but also so that they may preserve the right position of the piston in relation to its bore.

The piston must preserve the right clearances at top and bottom, and, upon wear in the bearing, a lining-up by distance pieces must be resorted to, so that the piston will return to its original position. To realize the desired amount of clearance quickly by the adjustment, some engineers employ trammels to show how far a certain mark on the piston rod or cross-head should stand with relation to a convenient, un-

changeable face on the cylinder casting. Others prefer to put marks on the guide and on the slippers, which coincide at the extreme positions of the piston.

The wear in the brasses is taken up by reducing the thickness of the distance-pieces between the two halves of the bearing.

Frequently, thin shims of sheet metal are taken out, until the bearing clamps the pin when screwed or keyed down hard. The shims are then replaced in sufficient thickness to realize the desired clearances. Thin shims should be well secured to prevent them from getting adrift and from falling out under motion of the engine.

The adjustment of the brasses should be such that the connecting rod will continue to swing in a plane through the axis of the cylinder and square to the faces of the slipper guide. With divided upper connecting rod brasses, extra care is necessary to realize this result, as well as to make sure that both bearings, or both links, receive their full share of the bearing pressure.

In beam engines the walking beam should swing truly in this plane, and adjustment of the pin bearings should continue until this result is accomplished.

582. How is the shafting overhauled and adjusted?

The shafting must always remain in a straight line, in order to prevent such strains by bending, as, under the constant reversals in each revolution, may soon lead to fractures. A careful examination and realignment, in case of wear, will, therefore, be necessary. The axis of the shafting should be square to the line through the centre of the cylinder, and also square to the plane in which swings the connecting rod. The crank pins should be exactly parallel to the axis of the shafting.

The wear generally takes place in vertical direction, and the

task of lining-up consists generally in raising the shaft uniformly, or on one end more than on the other. A line of sight, parallel and above the normal axis of the shaft, is usually established in more or less permanent form, and is located by centre-punch marks on bulkheads or parts of the ship. From these centre punch-marks and additional sighted horizontal battens the position of the shaft is located by fixed trammels, which should barely touch the top of the shaft. The sight line may be easily corrected for deformation of the ship, and, if once established, indicates the difference between the actual and desired position of the shaft.

Each bearing, in its lower half, must be lined up, until the shaft is at its right height. The top brasses are often fitted to the shaft by first measuring the clearance over the pin, when screwed down hard. This is done by little balls or rolls of stiff putty, or by pieces of lead wire, which are squeezed flat by the top brass, so as to indicate, at each end of the bearing, the exact clearance. The reduction of this clearance is then easily accomplished by filing the distance pieces or removing shims.

The accuracy of the lining-up of shaft and connecting rod can be tested, also, by successively turning the crank into several positions of a revolution, and by comparing the clearances on each side between crank webs and connecting rod brass. The connecting rod brass should be just free from the pin and free to swing.

Several faults may be found:

(1.) The upper connecting rod bearing, if divided, may have been raised more on one brass than on the other, drawing the lower bearing of the rod to one side, and letting it bear only on the edges, at the same time pressing always against one crank web.

(2.) Another fault may result when the crank pin swings in a

plane, not coinciding with the plane of the connecting ro and cylinder axis. In this case the lower brass of the rod wi press against one web in the top position, and against th other web in the bottom position.

583. What test on alignment is made by the differen sections of the shafting?

One section of the shafting may furnish a test of the accu racy of alignment of its neighboring section at the couplings. After the coupling bolts are all drawn, the two coupling should touch each other all around their circumference an remain so, even after one section is turned 180 degrees.

584. How is the thrust bearing overhauled and adjusted

The thrust bearing requires attention to make sure that a the thrust collars bear uniformly on the rings, or horseshoes. With shafts that are out of alignment, it may happen tha the collars bear more on the top than on the bottom of th horseshoes, thus tending to tip them, and eventually to brea them loose, from the clamping nuts on the side screws. I such a case the shaft must be aligned, or otherwise the who thrust bearing must be raised on one end, until the face of th horseshoes is again square to the axis of the shaft, coincidin with the faces of the shaft collars.

585. How is the valve gear overhauled and adjusted?

In the same manner as the piston, the valves also must b retained in an exact position relative to the ports. This true, since the whole steam distribution depends upon th position. The wear and slack in the valve gear bearing surfac must, therefore, be taken up with due regard to this positio Trammels are frequently employed, in order to establish a retain a fixed distance between a punch mark on the val stem and the face of the valve stem guide.

The wear in the link block brasses is generally taken up

placing shims under the brasses. The valve stem end brass, eccentric rod brasses and eccentric straps are generally fitted with shims, to allow an easy and rapid taking-up.

In beam engines the rock shaft bearing may require taking-up; the valve stem arms are ascertained to be secure on the lifting rods, also the dash-pots, gear and drop arrangement of Sickles' cut-off gear must be inspected for indications of wear, such as would interfere with its correct working.

586. When is it necessary to set the valves?

Valve-setting is resorted to when the valve does not perfectly perform its steam-distributing function. Indicator diagrams, taken on the last voyage, will have given a possible clue to the desirable adjustments. A valve diagram furnishes the best means for correcting the faults, and setting the valve at a position advantageous for timing of the four periods of the steam distribution.

587. What parts of the valve gear are important in the setting of the valve?

(1.) The centre position of valve in regard to ports.
(2.) The steam and exhaust laps.
(3.) The stroke of the valve.
(4.) The lead and angular advance of the eccentric.

588. What measurements are taken for construction of the valve diagram and for setting the valves?

(1.) Widths of top and bottom ports.
(2.) Widths of top and bottom parts of valve.
(3.) Distance between edges of ports.
(4.) Distance between valve face edges.
(5.) Largest opening of the top and bottom ports.
(6.) Length of the stroke.
(7.) Amount of lead in the top and bottom ports.
(8.) Angular advance of the eccentric.

589. What is indicated by the widths of the ports and valve faces?

The widths of the ports and valve faces give, for top and bottom, respectively, the sum of the steam and exhaust laps by subtracting the widths of the ports from those of the valve faces. For example: If the top port is $1\frac{3}{4}$ in., and top valve face is $2\frac{3}{4}$ in., then the sum of the top laps = 1 in. Also, if the bottom port is $1\frac{3}{4}$ in., and bottom valve face is $2\frac{7}{8}$ in., then the sum of the bottom laps = $1\frac{1}{8}$ in.

590. What is determined by the distances between port edges and valve face edges?

The distances between port edges and valve face edges give, for the steam edges, the sum of top and bottom steam laps, by subtracting the distance between port edges from that between valve face edges, repeating the subtraction for the exhaust edges, respectively. For example: If the total distance between the steam edges of the ports is 24 in., and the distance over the valve face steam edges is $25\frac{5}{8}$ in., also total distance over exhaust edges of port is $20\frac{1}{8}$ in., and between valve face exhaust edges is 20 in., the sum of the steam laps = $1\frac{5}{8}$ in., and the sum of the exhaust laps = $\frac{1}{8}$ in.

591. What is determined by the maximum openings at top and bottom?

The maximum openings at top and bottom give the extreme positions of the valve in relation to the steam edges of top and bottom ports. From these and the total distances the stroke and all of the laps in the normal centre position of the valve can be found. For example: The maximum opening of top port is $1\frac{1}{8}$ in., and the maximum opening of bottom port $\frac{1}{4}$ in.; after deducting these from 24 in., the distance betwee

the steam edges of the ports, 21⅝ in. is found as the distance between the positions of the edges in the extreme positions.

If 21⅝ in. is now subtracted from 25⅝ in., the distance between valve face steam edges, then the stroke is determined to be 4 in.

592. What does the stroke determine ?

The stroke will give all the extreme and centre positions for steam and exhaust edges.

If the maximum openings are subtracted from the half stroke the top steam lap in the example is found to be ⅞ in., while the bottom steam lap is found to be ¾ in. From the widths of the ports and of the valve faces, the top exhaust lap is found to be ⅛ in., while the bottom exhaust lap is found to be ⅜ in.

593. Of what value is the determination of the laps and of the stroke ?

The laps and the stroke alone can give considerable insight into the probable steam distribution, since they allow a comparison between top and bottom lap, and also give the proportion of the laps to the stroke.

Steam laps should be fairly equal, being slightly smaller at the bottom than at the top, while exhaust laps should be larger at the bottom than at the top. The steam laps also should not exceed ¼ or ⅓ of the total stroke.

Should the valves be set too high or too low on the rod, indication of the misplacement would be shown by the laps and the stroke.

If the laps should be very unequal and an extra large steam lap associated with an extra small or even negative exhaust lap, and the maximum openings, also, in consequence, very unequal, then a raising or lowering of the valve will probably be the required remedy. By a little addition or subtraction, to

or from the laps, the engineer can find very quickly how much the valve should be lowered or raised, to obtain the probable best setting of the valve.

594. What does the lead determine ?

The lead determines where the valve stands, when the piston is in its extreme position, and also, with consideration of the length of the eccentric rod, the angular advance of the eccentric.

The lead, as explained in the chapter on engines, is the advance opening of the steam port, and is measured with the crank at the dead centre.

595. How do engineers determine when the crank is at the dead centre ?

The movement of the cross-head is exceedingly slight near the extreme position, even if the crank swings through an arc of some magnitude. It is easier to find, first, the positions of the crank, equally distant from the dead centre, and in those positions, where the movements of the cross-head are sufficiently observable. The crank is then turned somewhat beyond the extreme position, and marks are placed at coincident positions on the cross-head and on the guide. Marks are also placed on the circumference of a shaft coupling, having reference to a stretched cord, or to a pointer extending from the nearest bearing or support.

The crank is then turned back over the dead centre, until the mark on the cross-head again coincides with the mark on the guide, and a new mark is placed on the coupling, as determined by the cord or pointer. By finding the middle of the distance between the two marks, and turning it under the cord or pointer, the crank is placed on the dead centre at which position the lead or opening in the corresponding port is measured.

596. How can the angular advance of the eccentric be measured?

The angular advance of the eccentric can be measured in relation to the position of the crank on the same coupling by finding the dead centre position of the eccentric in reference to the same cord or pointer.

The distance on the circumference of the coupling, between the dead centre mark of the crank and the dead centre mark of the eccentric, will bear the same relation to the total circumference of the coupling as the angle between crank and eccentric bears to 360 degrees. After measuring with a tape line the total circumference, and the distance between marks, the result in degrees may be determined by a simple proportion.

597. What conclusions may be drawn when the lead and the angular advance are known?

When the lead and the angular advance are known, a valve diagram can readily be constructed, and the desirable changes or setting may be effected.

If the lead should be too large, much more than $\frac{1}{4}$ or $\frac{3}{8}$ in., it would indicate that the angular advance of the eccentric is too large, while either none or a negative lead would indicate too small an angular advance.

598. What factors should be considered in setting the valve gear of a beam engine?

The factors in the setting of a beam engine valve gear are the position of the cams on the rock shaft, and the angular advance of the eccentric, both for the exhaust as well as for the steam gear.

The swing of the cams is effective only in the upper part, for raising the lifting rods and valves, and correspondingly more or less as the cam is turned up or down. The angular

advance of the eccentric determines at what part of the stroke of the piston the lifting shall take place.

599. What are the functions of the steam toes, and how can their influence be altered?

The steam toes should lift slightly in lead when the piston is in its extreme position and should cut off the steam after a certain percentage of the piston travel, shown in Fig. 101 shortly before 0 and after 8.

If the steam toe is bodily turned up around the rock shaft the lead will be increased, and the cut-off will take place later, while the maximum lift of the valves will be increased.

If the steam toe is turned down, the lead will be decreased and the cut-off will be earlier, while the maximum lift of the valves will be decreased.

600. How can the lead and point of cut-off be measured?

The lead can be measured from some convenient point of the lifting rod, and marked on an index scale alongside of the rod, fastened to one of the guide bearings.

The point of cut-off can be measured and marked on the cross-head slide.

The dead centre position of the crank is determined as before described.

601. What conclusions can be arrived at when the lead, the cut-off and the angular advance are known?

When the lead, the cut-off and the angular advance are known, they indicate what steps to take for correction of any faults in the steam distribution. For example, if the cut-off is too late, then the angular advance should be increased, and the steam toe turned down, until the lead is again up to the desired amount, thus reducing the cut-off.

A short rule is as follows: The period of admission will extend approximately over a crank angle equal to 180 degrees,

minus the angle of advance of the eccentric, in Fig. 102, where the angular advance is 30 degrees. This period will extend over about 150 degrees. Therefore, the cut-off will take place after the crank has traveled around about 150 degrees.

602. In what respect do the operation and setting of the exhaust cams differ from those of the steam cams?

The only difference in the setting of the exhaust cams is that the cut-off of the exhaust, or the commencement of the period of compression, takes place when the piston is very near to the end of its stroke.

The operation of setting is the same as for the steam cam: A certain angular advance, usually between 10 and 20 degrees, is selected; then the cam is set to a good lead, usually between $\frac{1}{8}$ and $\frac{3}{8}$ inch, and the point of the commencement of the compression is found.

603. What point should be observed in turning and setting the cams?

Care should be observed, in setting the cams, that they are not turned up too high, so as to lift the valves too much. In such case the cams would bear on their sharp points, and not on their rounded faces, as intended.

The other point to be observed is that the cams are not turned too low, but lift the valve sufficiently high to give good opening for the steam and prevent throttling.

604. How is the condenser overhauled?

The condenser is overhauled by cleaning and inspecting the steam, the water space and the tubes, as well as by testing and repacking the tubes. The water chests are taken off and the manholes and hand-holes in the steam space taken out.

The grease and sediment is washed carefully from the tubes and the side of the steam space, or if the tubes are strongly coated with oil, boiling out with soda solution is resorted to.

The soda boiling is best done in port and the whole solution afterwards discharged in order to get rid of all the oil and remove the possibility of its getting into the boiler. For the inspection of the tubes, as regards cleanness, as well as possible corrosion, a few of them are drawn and their condition determined.

Before replacing the water chests, a test pressure, frequently about 20 pounds per square inch in the steam space, will reveal any leakage around the tubes. A careful packing of the tubes will result in little leakage of salt water and comparatively clean boilers; little scale, and good efficiency of steam generation.

The bottom of the condenser may require some cement to make an easy flow of the water to the air-pump channel.

605. How is the air pump overhauled and inspected?

The air pump is inspected thoroughly to determine the condition of the valves, for broken or loose studs, and leaky or worn flaps or discs.

It is essential to ascertain that the guards support the valves well in the open position.

The piston should receive attention as to its packing. This should be replaced, if worn, or set out and adjusted.

The nut holding the piston should be examined, in order to make sure that it is screwed down and locked.

In bucket pumps the lower connecting rod pin bearing may require taking up of the slack, and the bucket should receive a thorough cleaning out.

All bolts and studs are examined in order to determine whether they work easily in their nuts, without slackness, and that they are cleaned and freed from rust, so that an opening up and closing of any part of the air pump can be done quickly and effectively while on the voyage, when time is valuable.

The beams and links should be readjusted and any slack in the bearings taken up.

The hot well and air-pump delivery should be examined for tightness of the pipe connections.

It should be thoroughly cleansed from grease and sediments, care being taken to have the feed pipe, outboard delivery pipe and vent or overflow pipe openings clear and unobstructed. Where water gauges are fitted, they may need new glasses or new washer packing, with an overhauling and cleaning of the connections.

606. What overhauling is given to the circulating pump?

The circulating pump receives attention in the bearings of the runner shaft, where the lignum vitæ may need to be replaced, if much worn. The pipe joints and the run of the piping should be examined in order to correct sagging of parts and accumulation of air in pockets, which might spoil the circulating power of the pump.

New air cocks may need to be placed, if the piping cannot be refitted.

607. What attention do the reciprocating pumps receive?

The reciprocating pumps are examined mainly for the tightness of their automatic valves and tightness of the piston packing.

The nuts of the piston rod and the studs holding the valves, or seats, are firmly secured, if loose, or replaced by new ones, if broken. The cover bolts and studs are put in manageable condition for rapid access to valves and pistons.

608. What attention is given to the steam cylinders and valve gears of the independent auxiliaries?

The steam cylinders of the independent auxiliaries are examined for tightness of their pistons in the barrel, with setting

out of old or fitting of new rings. All the working parts are well overhauled, taking up the slack in the different bearings of the connecting rod, crank shaft and valve gear, and all parts are well secured against the possibility of getting adrift during the voyage.

The valve gear of the reciprocating auxiliaries are inspected to determine whether the pumps keep their right full stroke, or whether their tightness is sufficient to hold the steam well. The valve gears of the revolving auxiliaries are examined for the position of the valve on the rod, the position of the eccentric and the tightness of the valve.

609. What attention is given to the auxiliaries outside of the machinery space?

Aside from inspection of their steam cylinders and valve gear, the outside auxiliaries receive attention in the gears and countershafts to ensure that they mesh well into each other and that they are not slack in their bearings.

In the winches the chain barrels may require fitting with new chains, while the steering engine may require adjustment in the transmission line, from the hand-wheel to the reversible valve.

The ash-hoisting gear may require new ropes or shifting of the pulleys.

610. What overhauling is given to the piping?

The piping requires a careful inspection for weak places. Leaky pipes and joints are taken apart and replaced by new ones. The piping in the tanks or bilges requires a thorough examination for corrosion. The steam pipes, or pressure pipes, may need to be retested by hydrostatic pressure before they are covered again with non-conducting material. The valves and cocks are refitted and a thorough tightness ensured.

Additional drains for water in the steam pipes, or valves, are placed wherever pockets may have been found to exist, while air outlets are placed on pockets of the water pipes.

611. What parts require attention when the ship is placed in dry dock?

(1.) Sea valves.

(2.) Shafting, stern tube and propeller.

612. How are the sea-valves overhauled?

The sea-valves are of the greatest importance for the safety of the ship and great care is exercised by the engineers in their inspection.

The gratings of the suction valves are taken off and thoroughly cleaned, straightened or replaced by new ones, The necks of the valves are cleaned, and the zinc protecting rings are taken off. The condition of the hull material in steel vessels is carefully inspected to see if the zinc ring has performed its full duty.

The riveting of the reinforcing rings and the bolting of the sea-valve casings is overhauled, and every defective rivet or bolt is recaulked or set up tight.

The bottom blow valves frequently show considerable wear around the openings, and the spigots or lips may require refitting, if severely worn. In wooden hulls the caulking around the openings is renewed, if loose or worn away. The openings through the wood are required by some engineers to be fitted with lead sleeves, before the neck or valve is fitted. This lead sleeve is expanded tightly into the wall of the opening to prevent any leakage into the interstices between the parts of the material. The ends of the sleeve are flanged down into a recess, and nailed down, water-tight, with packing, if necessary.

The bolts of sea-valves in wooden hulls are liable to give

trouble by leaking. It is, therefore, advisable to use studs with wood screw thread for tapping into the wood, while bolt thread and nuts on the upper ends allow removal of the valve without disturbing the part of the bolt in the wood.

613. How is the stern-tube overhauled?

The stern-tube is overhauled in the stuffing-box and in the bearings. The stuffing-box may be worn in the bottom collar or in the gland, in which case new bushings are fitted. The gland studs, or bolts, may require fastening or tightening in the bulkhead or collar flange, and are cleaned and oiled to make them work easily for uniform and nice adjustment of the stuffing-box.

The bearing sleeves are taken out, in order to reveal the condition of the lignum vitæ strips, which must be renewed if worn much. The bearing sleeves in wooden boats may require refitting as well as lining-up and reboring, to suit the right shaft axis after large repairs. The studs and bolts are all well secured with locked nuts, in order to make sure that nothing gets adrift, when under way.

The cock used for drawing water from the stern tube is re-ground and put into thoroughly serviceable condition.

614. What attention is given to the propeller?

The fit of the propeller on the cone of the shaft must be perfect, and the hub well secured by drawing it up tight with the nut or key, and these securely locked. The water-tight cap, over the end of the shaft, is examined for water-tightness and all bolts and studs are fitted well and locked.

Frequently the cap is completely filled with hot tallow, which, if well poured, prevents the sea water from corroding the end of the propeller shaft. The forward face of the propeller boss extends generally over the brass liner of the shaft, to keep the shaft from corroding. If not very carefully fitted

however, the water will leak in. This may be prevented by compressing a few strands of packing under a cup-shaped collar in halves, which makes the joints tight.

Propellers with loose blades are examined around the flanges of the blades for loose studs or nuts, which may require tightening. The blades, if bent, are straightened out, or replaced, while cast steel blades, if honeycomed at the tip, may have the corroded parts chipped off or filled with cement.

With bronze blades, on iron or steel hulls, zinc slabs are fastened on sternport, shaft struts, rudder post or near lying parts of the plating to neutralize, as much as possible, the injurious effects of galvanic action on the steel.

615. What attention is given to the shafting?

The shafting, if fitted with brass liners, is examined very carefully for any possible indication of corrosion. The liners are removed, if any doubt exists, and carefully refitted or left off, as many engineers prefer all steel shafts, which, in single screw steamers, sometimes run in a bath of oil and tallow that fills the entire stern tube and keeps the water out. In this case, a shallow stuffing-box is fitted at the outside end of the stern tube. In twin screw ships the fair water sleeves, on coupling or shaft struts, are put in good condition, straightened and refitted, if bent, and all bolts are well secured.

616. What is done to place the machinery in condition preparatory to a new voyage?

After making all the repairs and adjustments required by condition of the parts, or permitted by available time the parts are again assembled, the packing replaced, or renewed, and the stuffing-boxes are packed and screwed down lightly.

The lubricators, oil cups and distributing pipes are replaced, refitted with wicks, or made ready for the reception of the oil.

The safety guards and swash plates are replaced, oil tanks and feed tanks cleaned and filled, the wrenches, tools and spares stowed in their receptacles, or lashed securely to their seatings.

The engine room and shaft alley are cleaned and everything not required for the voyage is removed, in order to complete preparations for getting up steam.

617. What precautions are taken in coaling?

Before the coal is taken into the bunkers they are all cleaned out and receive a fresh coat of paint, sufficiently in advance to be dry when coal is taken in. The stiffeners and braces are examined to see if they are bent or have loose or broken brackets or rivets. The doors are oiled and inspected for easy and quick operation in closing on their seats nicely, if required to be water-tight. If temperature or sounding tubes are fitted in the bunkers they are cleaned out and secured, so that no coal can get into them.

Platforms of wooden planks are laid under the coal scuttles to break the fall of the coal, and the ceiling on the floor, and up at the sides, is thoroughly repaired and made tight, to prevent coal dust from finding its way into the bilge and the suction ends of the bilge pumps. If any coal remains in the bunkers it is shifted nearest to the doors and so used first on getting up steam.

The coal is taken in as dry as it is possible to obtain it, to prevent decomposition, and eventual spontaneous combustion. The stowing is carefully superintended by the engineer to get all the corners full, and the coal is stowed uniformly to the same level. The arrangement for ventilation is put into efficient condition, to carry off all gases that may generate from the coal.

CHAPTER TWENTY-FOUR.

LAYING-UP MARINE MACHINERY.

618. What is understood by the term laying-up marine machinery?

Laying-up marine machinery means putting it in such condition that it may remain unused for a more or less extended period of time without impairing its further usefulness.

619. What is the principal danger that must be guarded against in laying-up?

The principal danger, threatening to impair the future usefulness of the machinery, consists in rusting and corroding.

620. How are the external surfaces of the boiler prepared for laying-up?

After the boiler is cleaned and inspected—as described in Chapter XXIII., under the heading, Care and Overhauling in Port—all loose parts, such as grates and grate-bearers, are stored in a dry place, and the furnaces, combustion chambers and tubes are given by some engineers a thin coat of linseed oil, after being first thoroughly dried.

If the lagging shows defects or signs of corrosion it is generally advisable to remove the defective parts and to give a good coat of red lead paint to all exposed surfaces. Thorough cleaning and scraping and subsequent painting is especially needed on the lower surfaces that are exposed to moisture from the bilges.

621. How is the interior of the boiler prepared for laying-up?

The interior of the boiler, after being cleaned, is thoroughly dried and must be kept dry, as moisture is the agent that promotes rusting and corrosion.

622. What means are employed to keep the interior of the boiler dry?

To keep the interior of the boiler dry some engineers make use only of the natural circulation through upper and lower man and hand holes. Others place flat vessels, filled with quicklime, for the absorption of all moisture into the boiler, and then close it up tight.

623. How are the fittings of the boiler prepared for laying-up?

The fittings of the boiler are taken apart, cleaned, and, after being greased with a slight coat of clean tallow, are put together again without packing. To make sure that no rusting or sticking takes place, the valves and cocks are moved occasionally. The sea valves and bottom blow valves, or cocks, must be put into serviceable condition, with complete packing at the time of docking, as it is desirable to keep the water and moisture out of the ship as completely as possible.

624. How is the engine prepared for laying-up?

The engine must be protected in the same manner as the boiler against the influence of rust and corrosion.

Particularly on the finished surfaces, such as piston and valve rods, cylinder bores and valve faces, as well as on all the bearings, a great impairing of the future usefulness of the engine would take place, if rust should deprive them of their smoothness and condition of least friction.

The remedies applied are, in this case also, protecting coats of paint, oil or tallow, and the prevention of condensation by ensuring a dry surrounding atmosphere. All rough surfaces may be painted, while the finished surfaces receive coats of heavy oil, tallow, or a mixture of tallow and white lead, which latter adheres very firmly and possesses at the same time considerable body and lasting qualities. The copper, brass or bronze parts are naturally more immune from corrosion than the steel parts, and the latter, therefore, require the greatest attention and an occasional inspection, to see that the protecting coats have not been rubbed off. The bearings of the shafting may hold moisture that would corrode the lower part of the shaft, if plenty of tallow is not applied to the lower brass. An occasional turning over of the engine with the hand turning gear is a wise precaution to make sure that nothing rusts tight.

The greatest care should be taken to remove all water and moisture from the engine, and no protective coating should be applied to any part of the machinery that is not dry and at least moderately warm.

All drain cocks should be kept open, and the engine turned several times for the complete removal of all water. If a systematic inspection of the ports or any pockets of cylinders, liners, valve chests, stop and other valves should reveal any water lodging in these pockets, it should be sponged out or a little hole drilled for drainage. In localities where freezing weather is likely to be endured by the laid-up machinery, this proves of the greatest importance, as such imprisoned water, upon freezing, expands, and is very apt to crack the casting or the part in which it is contained.

625. How are the auxiliary machinery and piping prepared for laying-up?

The auxiliary machinery and piping are prepared for laying-

up in a manner similar to that used with the main engine. All rough parts may receive a coat of paint or linseed oil, while the finished parts receive a coat of heavy oil, of tallow, or of a mixture of tallow and white lead.

The drainage of water should be as complete as for the main engine. It is better to drill small holes or to take down the valves or parts than to allow water to lodge in any pockets of the condenser, pump cylinders, pipes, valve chests, manifolds, etc.

A great deal of expense, in way of repairs, can be avoided by faithful attendance to these precautions.

626. What precautionary measures should be taken in regard to engine and boiler rooms?

The preservation of the efficient and useful condition of the machinery depends upon successful protection against condensation of moisture. There are two factors generally influential in preventing the precipitation of water from the atmosphere: The first is to keep the air as dry as possible by preventing its absorption of moisture from water in the bilges or open tanks.

The second is to keep the air, as uniformly as possible, at an average comfortable temperature which will prevent sweating or throwing-down of the moisture.

It is apparent that the accumulation of large masses of water in the bilges would readily furnish great quantities of moisture and the bilges should, therefore, by frequent pumping, be kept as dry as the condition of the ship will allow. All water tanks should be kept empty, or, if water is needed, should be supplied with tightly-fitting covers, in order to prevent evaporation.

As is well known, air of low temperature can hold suspended moisture less easily than warm air, which tendency finds its climax in freezing weather, when the moisture is nearly all

thrown down in form of frost or ice. By keeping fairly dry air, at a relatively high temperature, the dangerous "sweating" can be largely avoided. In localities where the laid-up machinery is exposed to freezing temperatures it is found advantageous to provide for artificial heat, in some form, in the engine and boiler room. This helps to keep the temperature of the air and the machinery as nearly uniform as the conditions will allow. On the other hand, too high a temperature, say above ninety degrees Fahrenheit, may be undesirable, as it may stimulate larger evaporation from the bilge water, or other sources, and thus add to the total humidity of the air.

CHAPTER TWENTY-FIVE.

CARE AND OPERATION UNDER WAY.

627. What steps are taken for the getting-up of steam?

For getting up steam the fires are built and kindled, the needed lamps and lanterns in the boiler room, passages and coal bunkers are lighted, and the water level brought to the right height. The bottom blow valve is inspected again to make sure that it is tightly closed.

628. How is the fire built?

Engineers frequently build fires by filling the after two-thirds of the grate with coal about five to eight inches deep, and filling the forward third with a stack of heavy sticks of wood, covered with coal up to nearly the top of the furnace. Oily waste is placed in the interstices of the wood and the front for lighting the pile.

The ash-pit door is kept closed and the furnace door open after lighting until the fire has burned thoroughly through the forward part and begins to spread over the after bed of coal.

The ash-pit door is then opened and the burning coal well distributed over the whole grate, being soon aglow under the draft.

629. What precaution should be exercised upon lighting the fires?

The fires, when lighted, should not burn with a strong draft, as unequal expansion of the material will cause leakage in tubes, seams or rivets. There is special danger in fire-tube boilers, where the great body of water in the lower part of the

water chamber remains quite cold, and is liable to set up severe racking strains, if the upper part is heated quickly by forcing of the fire.

630. What methods are employed to prevent this uneven heating of the water in large fire-tube boilers ?

One method employed to avoid the uneven heating of the water is the application of heat from an outside source to the water, more or less out of reach of the influence of the furnace fire. This heat is generally obtained in the form of steam taken from the donkey boiler, which is blown directly into the cold water through a nozzle system, similar to an ejector, thus, at the same time, aiding in the circulation and intermingling of the water. Another method employs the donkey pump, which draws the cold water off from the bottom and pumps it in again near the top through the feed check, thus circulating it thoroughly. Frequently the cold water is blown out by the bottom blow valve, and the boiler is filled up again with the pump, by which process the warmer water at the top gradually sinks to the lower parts of the boiler.

With such additional, artificial circulation, steam may be raised much more rapidly than when accomplished without such help, and it does not strain the boiler excessively.

631. Why is the air in the boiler allowed to escape and how is this accomplished ?

All water of normal temperature contains, under atmospheric pressure, a certain percentage of air, which is given up at boiling. This and the air in the steam space, if not removed, would get into the cylinders and condensers, and retard the vacuum. Another reason is that the presence of air would furnish a large amount of oxygen, which would be active in corroding the material of the boiler. Therefore, to remove the air, the water is boiled under atmospheric pressure by

lifting one of the safety valves and opening the upper test and water gauge cocks. The forming steam can then drive the air that escapes from the boiling water, or was standing above it, entirely out of the boiler.

632. What steps are taken when steam begins to form?

As soon as steam begins to form freely, the safety valve, test cocks and water gauge cocks that had been left open are closed. The steam gauge is examined and watched to see if it moves easily. The level in the water gauge must be frequently observed and the lamps that furnish the illumination at these two most important indicators put in efficient working condition.

The donkey pump is warmed up as soon as sufficient steam is formed, and slowly started for feeding the boilers. The easy fluctuations and slow rising of the water in the gauge glasses and the click and gradual cooling of the check valves indicate that the feeding proceeds successfully, and that the indications of the gauge glass are trustworthy and reliable.

All manholes and handholes are drawn up perfectly tight, and all joints are examined for leakage, or to see whether they require a last tightening for successful operation.

633. What steps are taken when steam is fully up?

When the full steam pressure has been reached, the draft is checked by closing the ash-pit doors. The opening of the furnace and uptake doors is not considered desirable, as too much cold air may be admitted, with the danger of straining the boiler. Some engineers lift one of the safety valves slowly and slightly, while others prefer to blow some of the water off by the surface blow valve, and then to feed again with colder water, thus checking the steam generation.

634. What preparations are made for starting the engine?

The preparations made for starting the main engine are fill-

ing the oil cups and lubricators and the warning-up of all parts, pipes, auxiliaries, cylinders, steam jackets, etc. The boiler stop valves to the auxiliary and main steam pipe are slowly opened a few turns, and all drains and drips are opened to let the condensed water escape freely.

The engine stop valve is opened, at first very slightly, to let only a small amount of steam into the valve chests. By turning the engine by hand several times, and after warming of the steam reversing cylinder by throwing links alternately into the extreme positions, the steam enters into both ends of the cylinders and gradually brings the cold metal parts approximately to the normal temperature of the steam.

The drain cocks are, meantime, left wide open to allow a free escape of all the condensed water and air in the pipes, valve chests and cylinders.

635. How is the condensing plant prepared for the starting of the engine?

The condensing plant, if already holding a vacuum before the starting of the engine, can aid materially in quickly getting under way. The possibility of obtaining a vacuum beforehand is one of the main advantages of the independent circulating pump and the air pump. After opening the sea-valves for suction and discharge of the circulating or condensing water, the circulating pump is started with steam from the auxiliary steam pipe, taking the same precaution of warming-up slowly and draining well.

Steam from the bleeder pipe is led into the condenser and condensed on the tubes. The independent air pump, or otherwise the donkey or feed pump, draws the water and air from the bottom of the condenser and discharges into the hot well, overboard, or into the boiler. The vacuum, thus caused and held, forms a powerful suction upon the low-pressure piston.

which helps to bring the engine quickly to the development of its full power.

636. How is the engine handled immediately before the start?

After the engine is fully warmed up, the oil cups for internal and external lubrication are again filled, and a few more turns of the stop valve are made, giving sufficient steam for a few slow revolutions forward and backward, until everything is proved to be clear and in good working order. The engine is then kept moving slowly, or is shut off again ready for the signal to start.

637. What is the principal work in the boiler room during the voyage?

The principal work in the boiler room during the voyage, aside fron the handling of coal and ashes, is:

(1.) Keeping the steam pressure by firing.

(2.) Preserving the water level by feeding.

638. How are the fires tended after getting under way?

The firing must be done in such manner that the prescribed steam pressure is held as steadily as possible. The ideal method of firing, as approximated with a gas or oil fire, is to produce from the furnace a steady flow of fire gases, of such temperature and such volume as will evaporate from the heating surface the exact volume of steam required for operating the engine and its auxiliaries.

639. How far is this condition realized in the ordinary manner of firing coal?

The ordinary manner of firing coal realizes, only in a limited way, a steady steam pressure, particularly in the case of water-tube boilers. The firing must be conducted so that the fluctu-

ations are, at least, held within the smallest range, by keeping the steam production at times a little above the normal, thus making up for the inevitable falling-below this average at other times. The factors that must be regulated are:

(1.) Amount and distribution of fuel.

(2.) Draft through the fuel.

640. How is the amount and distribution of the fuel regulated?

The amount of fuel required for the production of the steam is supplied through the furnace doors, uniformly and in fairly equal intervals, to all the furnaces in regular rotation, so that all contribute an equal share to the work. Some firemen supply a larger amount at longer intervals, while others prefer to give smaller quantities oftener.

The opening of the fire doors reduces the draft through the bed of fuel and so checks the combustion, at the same time adding cold air to the fire gases, and thereby reducing their temperature, with a consequent falling-off in the steam production and pressure. The doors should be left open, therefore, only the shortest possible time. The distribution of the fuel on the grate should be as uniform as possible, keeping an even thickness of the fuel, and not allowing the grate to burn bare in some spots, while deep piles lie in others. The air rushes through the uncovered places and lowers the temperature of the gases.

The coal is not used in large lumps but in pieces about the size of a fist, so that it can be evenly distributed over the grate.

The thickness of the bed of fuel depends somewhat on the quality of the coal and principally on the draft. The bed of fuel is of good thickness when the draft can just keep it burning well through its whole depth.

641. How is the draft through the fuel regulated ?

Natural draft is regulated by the ash-pit doors, and forced draft is adjusted by the revolutions of the fan. Both depend, for the effect of the air supply, upon the condition of the bed of fuel. When clinker and ashes have been formed on the grates, the draft will be checked and the combustion retarded. When the fire is clean, the draft is strong and the combustion good. The fire is kept in such condition that sufficient air finds its way through the bed of fuel for such combustion as is necessary to keep the steam pressure fairly steady.

A certain mean between the depth of the bed, the quality of the coal and the intensity of the draft, which will produce the least fluctuation, is soon found.

642. How is the need of cleaning the fire indicated ?

The need of cleaning the fire is indicated by a decreasing reflection from the fire in the ash-pit. The clinkers and ashes settle on the grates, close the interstices between the bars and thereby keep the air from getting to the fire above.

643. How is the cleaning of the fire accomplished ?

The cleaning of the fire is accomplished from below through the ash-pit doors and from above through the furnace door.

Ashes and small particles of clinker can easily be removed from below, particularly with shaking grates, but the heavy clinkers must be withdrawn through the furnace doors.

644. How often is this cleaning required ?

The frequency of cleaning depends somewhat on the quality of the coal, but for average conditions a thorough cleaning is needed once in from eight to twelve hours. Many engineers, however, prefer to clean fires in every watch of four hours, usually in the third hour.

645. How is the cleaning accomplished?

The cleaning is done when the body of fuel is well burned through and somewhat below its average depth. The good coal is raked quickly to one side of the furnace, the clinkers pried off the grate bars and withdrawn through the fire door. All the good coal is then transferred to the cleaned side, and the clinker is removed from the second half of the furnace. The burning coal is now well spread all over the grate and charged with fresh coal. If the fire should have burned down too much for complete covering of the grate, a little burning fuel from the neighboring furnace is taken. The clinkers are cooled with water and removed, together with the ashes.

646. What is the most important consideration in cleaning fires?

The most important point in cleaning fires is that it should be done quickly, so that the inevitable and injurious cooling of the fire gases and boiler may be as slight as possible.

647. What may cause the grate bars to fall out?

Grate bars may fall out when they burn through, or bend, under excessive heat or weight. They may be knocked off the bearers, also, during the cleaning from below or above.

648. What is done when the grate bars have fallen out?

New bars are put in the place of the damaged ones, with the help of special grate bar tongues and poking tools.

649. What is the principal cause for the burning of grate bars?

The burning of grate bars takes place principally when the amount of ashes in the ash-pit becomes so large as to obstruct the passage of the cooling air to the bars, which, in consequence, becomes very hot. The radiation of the glowing

ashes and clinkers may aggravate this influence to such an extent that softening and sagging of the bars takes place. To prevent this possibility, the ashes are frequently removed, cooled down by water and disposed of, at least once in every watch.

650. In what other place can checking of the draft occur?

The draft can be checked or retarded, also, when the passages through the tubes, in fire-tube boilers, or between the tubes, in water-tube boilers, are clogged, closed, or contracted by soot, ashes and cinders, particularly where a strong forced draft is employed.

For sweeping the tubes of fire-tube boilers, the fire is allowed to burn down fairly low; the ash-pit doors and uptake dampers are closed, and the furnace and uptake doors are opened. The sweeping is done as quickly as possible, either by hand, with a wire brush or scraper, or by a steam blast nozzle that pushes the obstructing particles back into the combustion chamber. The sweeping of water-tube boilers is generally done with a steam blast nozzle, as hand-cleaning proves insufficient and much slower.

651. How is the feeding, for the preservation of the water level, regulated?

The feeding should be regulated by hand, or automatically, so that the normal water level is preserved with the least fluctuation.

652. How is the regulation accomplished?

The regulation of the feed supply is accomplished by limiting the lift of the feed check valve to an opening that will pass the required amount of water.

With independent feed, or donkey, pumps the steam supply is adjusted, until the pump furnishes an amount of water equal to the evaporation of the boiler.

With large fire-tube boilers this may be accomplished with relatively little attendance, but in water-tube boilers a frequent observation of the water level and readjustment of the feed-water supply is required. For this type of boiler the automatic feed regulators prove great helps to engineers, although they never can be trusted absolutely.

653. What connection is there between feeding and firing?

The connection between feeding and firing is very clearly perceptible with water-tube boilers, though less pronounced in fire-tube boilers.

If the firing is irregular, and if, through long and frequent opening of the furnace doors, the evaporation is checked and the pressure has fallen, then less feed water is required, and the water rises in the gauge glass, if the same supply is continued.

In water-tube boilers, with small heat storage capacity, the drop in evaporation and pressure will be very pronounced, while the excess of feed water, being large in proportion to the free water surface, will raise the level rapidly.

In large fire-tube boilers, with great heat storage capacity, the drop in evaporation and pressure will be comparatively small, while the excess of feed water, being distributed over a large water surface, will raise the level very slowly.

The reverse takes place when excessive firing has quickened the evaporation and increased the steam consumption by accelerating the speed of the engine. More feed water is required, or the water falls in the gauge glass, if the same supply is continued, quickly in case of water-tube boilers, slowly in case of fire-tube boilers.

654. What precaution is exercised in the determination of the water level.

The water level is determined by the reading from the gauge

glass, or by the test cocks. The level in the gauge glass is watched and all connections blown through once in each watch, to make sure that no clogging of the passages has taken place. If the level, after blowing through, reappears smartly and with easy fluctuations, it is a sign of clear passages and reliable indication of the level. An easy following of the movements of the ship by the level in the glass also indicates to an experienced eye the clearness of the connections.

If the glass is full, a slight opening of the blow-out valve and closing of the water valve will bring the level down gradually, while it is sent back to the top upon re-establishing the normal condition. If the glass is empty and no indication of the level is received from the test cocks, the fire should be checked, as much as possible, and, through the uptake doors or casing covers, it should be determined if the upper part of the heating surface has been bare of water, and is so overheated.

It is considered best not to accelerate the feeding in such a case, as this is likely to cause sudden evaporation of large bodies of water into steam, which might lead to ruptures or explosions. Everything is allowed to cool down and careful observation is made, so that the extent of the damage may be determined, before feeding and putting the boiler again into service.

As the rolling or pitching movements of the ship may disturb the readings of the gauge glass, experienced water tenders judge closely, so as to keep the level sufficiently high that no part of the heating surface is exposed to the direct heat of the fire.

When the glass breaks the connections must be shut off and the test cocks used for finding the water level.

The automatic self-closing gauge connections, if simple and not easily deranged, are found convenient by many engineers.

The readings from the test cocks must be interpreted with

judgment and experience, as, under the movements of the ship or with a priming boiler, the cocks may discharge very moist steam, which is easily mistaken for water. As the greatest danger to the boiler lies in low water, the test cocks, in discharging all steam, will indicate this condition quite clearly, thus giving warning that investigation is needed. By discharging all water, with a high level, they serve, for the extreme cases, fairly well until the water gauges are placed again in working order. The new glass is carefully packed with the rubber washers, drawn up tight by the glands and then warmed up slowly and carefully to prevent breaking of the glass by unequal expansion.

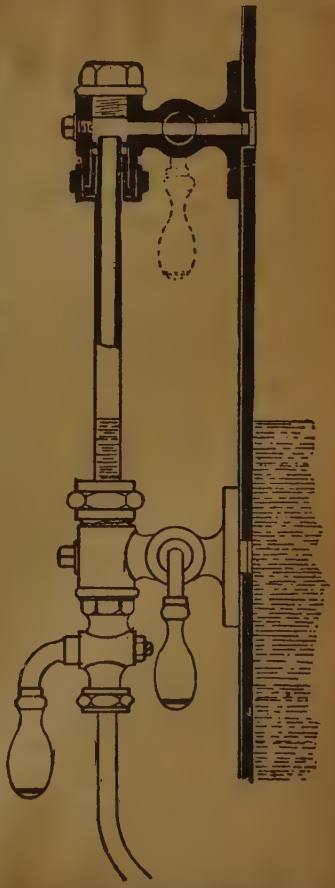


FIG. 184.—Part Sectional Elevation of a Water Gauge Glass, showing method of attachment to boiler shell.

655. How is the quality and condition of the water in the boiler determined?

The quality and condition of the water is determined generally in regard to:

(1.) Acidity.

(2.) Salt, scale and dirt.

656. How is the acidity of the boiler water determined?

The acidity of the boiler water is found by testing it with blue litmus paper, which turns red when the water contains free acid.

To prevent this acidity, which may cause corrosion of the boiler

material, the water is better kept slightly alkaline by add ing a solution of soda to the feed water, generally in the surfac condenser.

657. How is salt in the boiler water detected?

The salt in the boiler water is detected by the salinomete (Fig. 185). This is a tube with gradua tions and two bulbs, the lower of whic is loaded with a weight sufficient to le the tube float upright, immersed to on of the graduations, according to th density of the water. In fresh wate the salinometer sinks to the top gradua tion, 0, while, due to the greater densit of salt water, it floats higher and highe according to the increasing percentag of salt contained in the water, as ind cated by the scale of graduations.

FIG. 185.— A Salinometer. The upper bulb is the float, giving buoyancy to the instrument, the lower one is loaded, to secure floating in vertical position.

As sea water, on an average, co tains one part of salt to thirty-two par of water, the scale sinks to mark 1 i ordinary sea water. The graduatio generally extends to mark 4, at whic point the dangerous deposit of sa would commence. The percentage salt in the water, however, is not a lowed to rise above 3 and is preferabl less.

With modern boilers, feed heate and evaporators the danger from salt is remote and, for th reason, blowing-off need occur but rarely. The water f measuring by the salinometer is drawn off into a little pc where it is allowed to assume a certain temperature, general 200 degrees Fahrenheit, to which the graduation of the sa

nometer scale is adjusted. It is only at the special marked temperature that the readings of the instrument are right.

To save time, engineers have sometimes salinometers marked respectively for 190, 200 and 210 degrees Fahrenheit.

658. What is done to keep the water from depositing scale and foreign matter in the boiler?

The permanent deposition of scale or foreign matter in the boiler may be prevented in two ways, first, by forcing the water to deposit it before entering the boiler, or, secondly, by transforming it into such shape that it will not deposit as a hard scale, firmly adhering to the material, but can be removed in loose form by blowing-out.

659. Where and how is the foreign matter deposited before entering the boiler?

The foreign matter in the make-up, or feed water, may be forced to settle by heating it in the evaporator and the feed heater, or by filtering it in the feed-water filter.

In the evaporator, the feed make-up is freed from the salt and scale elements contained in the sea water. In the feed heater it is freed from all the scale or salt particles that are drawn from the injection condensing water, or that are introduced by the leakage through the tube ends of the surface condenser. The feed-water heater is effective, also, in freeing the water from air, and a large part of scum, oil and grease, which, upon heating, rises to the top of the heater, being left behind, so that the water may be drawn off well below the top of the heater, already comparatively clean.

The feed-water filter will retain the whole, or the remainder of the mechanical admixture of the water, mainly oil, grease and scum, and allow it to enter the boiler practically free from foreign matter.

660. How is the foreign matter in the feed water transformed for easy removal from the boiler?

The foreign matter in the feed water is transformed either by chemical or mechanical means. By chemical means it is influenced so that it remains soluble up to a certain density or is precipitated in granular or powdery form, easily removed by blowing-out or washing-out at intervals.

Vegetable substances containing acid, such as are sometimes employed for this transformation in the boilers of river steamers with fresh water feed, should be used only sparingly and with precaution, as any excess of acid attacks the material of the boiler and does more damage than good.

Caustic soda, salts of soda or ammonia, lime, etc., with more or less alkaline reaction, are generally found to be the best chemical agents to transform, or prevent, the deposit of hard boiler scale.

Such chemical means as are used for fresh water are kerosene or crude oil, which prevent the scale from adhering firmly to the heating surface, keeping it loose and spongy. They should be applied, however, in small quantities only, as particularly with crude oil, the water is inclined to foaming and priming, aside from the fact that the spongy oil and scale, covering the heating surface, retards the heat transmission much more than does the hard scale alone.

661. How are the blow valves used for the removal of foreign matter in the boiler?

The blow valves furnish the means for removing the foreign matter that remains loosely in the boiler water. Blowing, however, must be done with a certain amount of judgment as all the heat in the water blown overboard is entirely wasted.

The state of the water may be seen at the surface in the

gauge glasses, or is determined from a sample taken at the test cocks.

Particularly oil and grease, with scale particles mixed in, are found in form of scum floating at the surface, and are best promptly removed by the surface blow before they find a chance to settle on the heating surface.

A sample of the water taken at the salinometer cock often indicates the state of the water lower down and the advisability of using the bottom blow.

Care should be exercised in handling the blow valves, or cocks, to make sure of their condition, whether open or closed, as required, and to indicate, beyond any doubt, in which position they are. Some engineers fit the handles or wrenches in such manner that they can only be removed when the cocks are fully closed, and it is thus possible to know, even from a distance, what is their position.

662. What is foaming, or priming, of the boiler water?

Foaming, or priming, is a more or less violent ebullition of the boiler water, which causes the steam to carry particles of water with it, a condition dangerous to the safety of the engine.

663. How is foaming, or priming, observed?

Foaming, or priming, is observed in the gauge glasses, where the level of the water appears very unsteady, sometimes filling the glass altogether, at other times disappearing entirely. The water is also dirty and leaves a sediment on the glass.

664. What are the principal reasons for foaming, or priming?

Foaming, or priming, may result from sediment, mud or dirt in the boiler water, which forms a layer of scum at the surface. Another cause may be very irregular firing and feeding, or a very

sudden starting of the engine, with consequent large steam withdrawal.

The cause is frequently found in defects of design or construction, namely, too small a steam space, contracted water space, or too low a position of the entrance of the main steam pipe.

665. What precautionary measures are usually taken against priming in the boiler?

The precautionary measures consist generally in checking the evaporation by closing the ash-pit door and, in very severe cases, opening the uptake doors slightly. The boiler is also fed with clean water, and the surface blow used for the removal of the surface scum, while the stop valves are partly closed.

All drain valves on the main steam pipe and the separator are opened to keep the water, which is carried over by the steam, as far from the engine as possible. Superheaters are turned on full, as they materially help to evaporate the water lifted by the steam.

The water gauges and the test cocks are blown through frequently to keep the openings clear and free from scum.

666. What are the usual causes of boiler explosions?

Boiler explosions may result from an extra large strain on the boiler material, or from a weakening of the material itself, which will give way under the normal strain.

667. How may an extra strain upon the boiler material occur?

An extra strain upon the boiler material may occur by shock from the outside. Any work like caulking or chipping is carefully avoided, as it puts an extra strain upon the boiler material at that place, and may lead to rupture. Another reason for too much strain may be too high a steam pressure, which might

result from the sticking of the safety valves, a sudden stopping of the engine, or when lively evaporation furnishes large quantities of steam, while none is withdrawn or can escape.

668. How can weakening of the material occur?

Weakening of the material, and consequent danger of explosion, may occur by corrosion and wear, as produced by insufficient care in preservation, or by age and long usage. To determine such weakening, careful inspection of all the parts of the boiler should be made at the time of cleaning and overhauling in port, and a reduction of the working pressure decided upon by the officers of the steamboat inspection service, according to the extent of such weakening.

A temporary weakening of the boiler material takes place when overheated. This is the most probable and frequent cause of boiler explosions, against which constant vigilance is exercised during the active operation of the boiler. Particularly from two directions is the danger imminent, the first being from low water and the second from excessive scale. With low water the upper parts of the heating surface lose touch with the water, which alone is able to absorb large quantities of heat in such rapidity as to keep the metal at practically an equal temperature. On losing the cooling influence of the water, the temperature of the metal walls may rise to a point at which the strength of the metal is so much reduced as to cause the sheet to bulge and burst.

A weakening of the material is liable to take place also upon formation of excessive scale. Scale is not nearly so good a conductor of heat as the metal, and a thick layer of scale will retard the heat delivery of the material to such an extent that it becomes seriously overheated. This may lead to gradual bulging, or upon the cracking-off of the scale, a rush of water to the excessively hot metal may result in a very sudden steam

formation and a giving-way of the material under the increased and suddenly applied strain.

669. How is the boiler handled when the engine must be stopped for a short time?

If possible, a careful engineer will always send previous notice to the fireroom of his intention to stop the engine. The fires are allowed to burn down somewhat; the ash-pit doors are closed, and cleaning of the fire and sweeping of the tubes are then conveniently performed. The surplus steam is blown off through the safety valves, or discharged into the condenser by the bleeder, which saves all the steam for feed-water purposes.

The feed pump is kept moving and the surplus is blown off by the surface, or bottom blow, at such rate as the condition of the water shows to be desirable.

670. What is banking of the fire?

Banking of the fire is the drawing together of all the burning coal upon the forward part of the grate and the dead plate. It is practiced when the stopping of the engine is to continue for an extended period, checking rapid generation, while, at the same time, keeping the boiler under sufficient steam for a quick start. The steam is thus kept high enough, also, for effective operation of the donkey, or feed pump.

671. What is done when it is necessary to stop steaming operations in the boiler?

When it is necessary to suspend steaming operations in the boiler for cleaning and overhauling, the stop valves are closed and the safety valves, or bleeder valves, are opened, to get rid of the steam, while the fires are allowed to burn out, or are drawn and extinguished by water. Care is taken not to draw the fires until the steam pressure is low, and, also, to keep the water well above the heating surface. The doors of the fur-

naces and ash-pits are kept closed, after the drawing of the fires, to prevent unequal cooling and contraction as much as possible.

672. What points require attention in the engine room after the engine has started on the voyage?

The points that require the attention of the engineer are principally the lubrication and permanency of safe and economical conditions in the working of the engine.

673. What attention is given to the lubrication?

Lubricating material is provided in such quantities, and with such regularity, that all bearing surfaces remain cool and smooth, with a supporting film of oil between them.

The oil cups are filled at regular intervals, and care is taken that the normal amount has been consumed, as well as that the bearing has received it. The wicks may be lifted from time to time for a moment, to see that they are free from impurities or the drops in the sight feeds are counted. If the oil should not be of the usual quality, the supply may be profitably increased by adding a wick to each tube, or by opening the needle valve by a part of a turn. Many engineers prefer to give a rather excessive lubrication, at first, gradually reducing it to the minimum requirement, as determined by experience.

The piston rods and valve stems should be swabbed with oil at frequent intervals, at the start, to secure efficient lubrication in their stuffing-boxes.

The quality of the oil, and the need of more or less lubrication, can often be found from the revolutions of the engine, which may show an increase, or decrease, by one or more turns above or below the normal number.

The temperature of bearings is one of the best indications of their condition.

Oilers learn by experience to determine quite closely the temperature of even the moving parts by the touch of the hand, when they examine every bearing at regular intervals.

The noises about a moving engine also prove an effective help in judging of the performance of the bearing surfaces. A heavy pound may indicate too much slack, and consequent liability to heat under the reversal of impact.

Other helps are gained by the sense of smell, which can detect bad odor from burnt animal or vegetable oils; or by the sense of sight, if, in severe cases of heating, the anti-friction metal of the bearing should melt and run out.

674. What other points receive the attention of the engineer?

The observation by the engineer is extended to all parts of the engine and the auxiliaries, to see that every nut and bolt remains securely in its place.

He should be prepared to locate any unusual noise and its cause, as well as to apply a remedy for the trouble. The movements of the crank shaft are observed and a lookout is kept upon the clearances between the bearing brasses and the crank web. If the webs should bear upon the brasses endwise, a fault in the adjustment of the thrust bearing or its horseshoe collars would be indicated. The swing of the connecting rods, or of the eccentric rods and links, should be in the right plane without any side movements that might speedily produce heating and excessive wear.

The thrust-bearing collars should all bear uniformly, any irregularity being detected by the heating of one or more collars and by the comparative coolness of others.

675. What attention is given to the tightness of flanges and stuffing-boxes?

The flanges and stuffing-boxes are kept well tightened down,

in order to prevent loss of steam or access of air to those parts in connection with the condenser.

Even small leaks should be avoided, as steam lost in this way cannot be recovered, and many small leaks may mean quite a large total. Small leaks have a very annoying fashion of growing rapidly larger, to an ultimate blowing-out of the packing.

There is no difficulty experienced in keeping the stuffing-boxes tight, provided there is sufficient depth. Flanges must be heavy and stiff, fitted with a large number of well-fitting, strong bolts, in which case there will be little danger of leakage on any of the stationary parts.

676. How do engineers determine that the engine performs its work with good economy?

The economy of the engine's performance is determined from the indicator diagrams and from the amount of feed water that must be supplied to the boiler, for furnishing the quantity of steam needed for the continuous, regular operation of the main engine and its auxiliaries.

677. Why is it desirable to know the amount of the feed water, as well as the indicator diagram?

The amount of feed water tells the total quantity of the steam generated by the boiler, while the indicator diagram shows only that part of the steam which actually exerts pressure upon the piston. The amount lost by initial condensation and leakage, through valve, piston, safety valves, stuffing-boxes and joints, is not learned from the cards.

However, by comparing the amount of feed water with the amount of steam shown by the diagram, a percentage of efficiency of the engine as a steam-user may be found.

The engineer can, therefore, discover whether the engine is

wasteful or economical by noting the percentage of unuse steam.

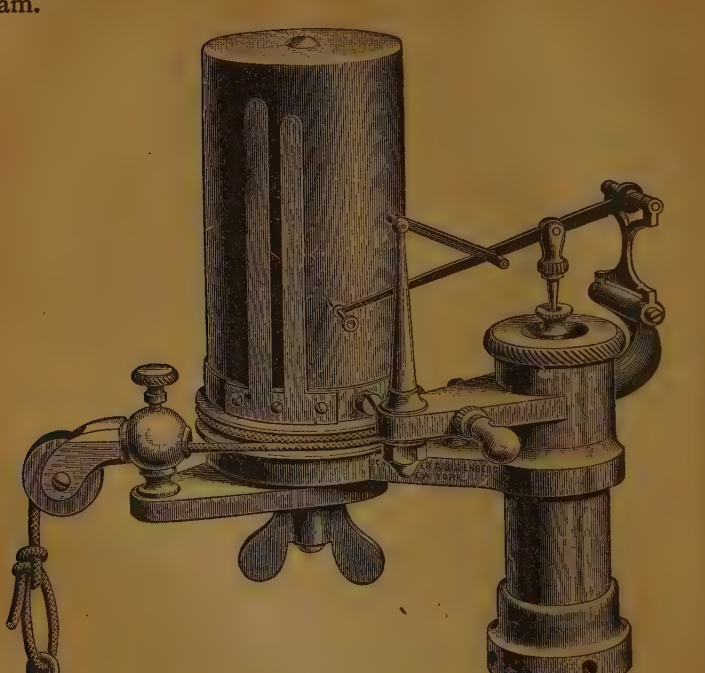


FIG. 186.—**One type of Steam Indicator, showing paper drum against which bears t** pencil point carried on the lever attached to the piston rod of the small cylinde also spring-controlled cord for rotating the drum from a reducing lever on t engine cross-head.

678. What are indicator cards, or diagrams?

Indicator cards, or diagrams, are records of the pressures every point of the stroke of the piston. These pressures a

indicated with reference to the atmospheric pressure and may be either above or below the same.

679. How is the indicator constructed and arranged ?

The indicator is the apparatus by which the indicator cards are obtained.

As shown by Fig. 186, it consists essentially of a little steam cylinder, whose nicely-fitting piston is actuated by the pressure of the steam from below, or by the pressure of the atmosphere and of a graduated spring from above. The piston is firmly connected to a small piston rod, which is jointed to the swinging pencil bar. The end of this bar carries a pencil, which, upon the raising or lowering of the piston, will describe a vertical line upon the circumference of the revolving cylinder, or drum, carrying the card. By cord connection and a spiral spring, this drum is revolved back and forth over an arc less than a complete revolution, coinciding with the stroke of the piston in end and intermediate positions. The cord pulls the drum out, tightening the spiral spring, which, upon release by the cord, exerts its tension to return the drum to its original position.

To adapt the long stroke of the engine piston to the short arc of the drum, a reducing gear is fitted, one form of which is shown in Fig. 189. This reducing gear is generally a straight or bell crank lever, the long arm of which is driven by the cross-head, while the short arm, or small sheave, is connected with a cord to the indicator drum. Another form of reducing gear consists of a double pulley, a large one with cord connection to the cross-head, and a small one carrying the cord which moves the paper drum. The two pulleys are firmly connected for simultaneous action, and are rotated in one direction by a spiral spring, which is coiled up and placed in tension when the cross-head cord turns the pulley the other way.

To make the use of the indicator convenient, it is screwed

into the permanent socket of a pipe extending to both ends of the cylinder, and with either one of which it can be connected or disconnected by a three-way cock.

This pipe connection is permanently fitted on each engine

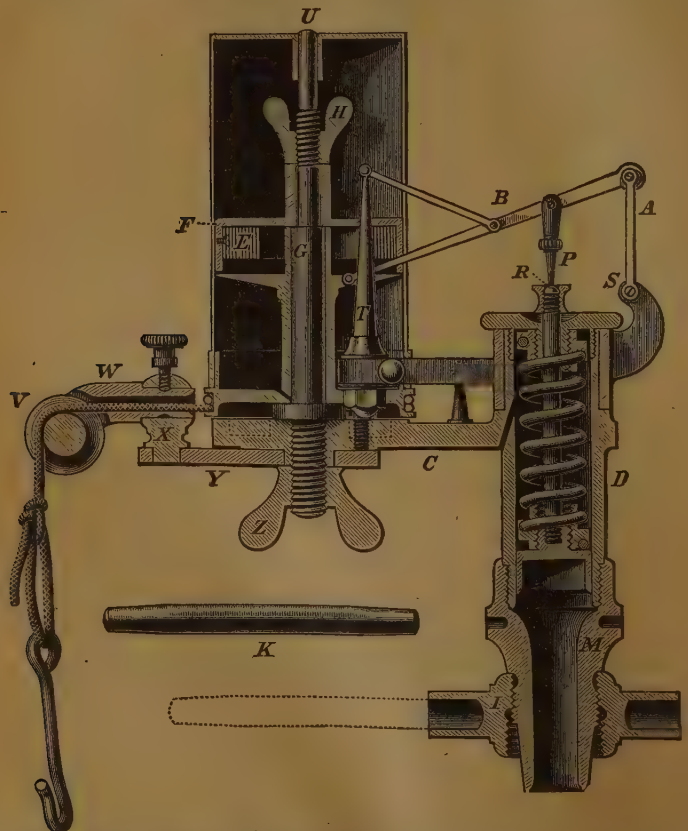


FIG. 187.—Sectional Diagram of the Indicator. A is the swinging bar; B, the pencil bar; C, the frame indicator; D, cylinder containing tension spring; E, coiled spring on drum roller; F, revolving cylinder or drum; G, drum pin; H and Z, thumb screws holding drum; I, nut to connect indicator to pipe; K, lever for screwing up I; M and N (Fig. 188), connections between the spring cylinder and pipe; O (Fig. 188), specially small piston; P, piston rod; R, joint; S, pin; T, post for guide of pencil bar; V, guide pulley for cord from reducing lever; W, swivel sleeve for cord; X, swivel pin; Y, support for swivel pin.

cylinder in such a position that an easy lead of the cord from the reducing gear to the drum is obtained.

680. How are the indicator cards obtained?

The indicator cards are obtained by the rising or falling of the pencil, pressed against a sheet of paper on the circumference of the revolving drum.

The pencil will rise or fall, as the piston is pushed up by an excess of steam pressure, or as it is forced down by the pressure of the atmosphere and of the spring. If through a small three-way cock the atmosphere is admitted to the space below the indicator piston, it will assume a position where the spring is practically without tension and where balance is established between the atmospheric pressure above and below. If the drum revolves in this condition, the pencil will neither rise nor fall, but will describe a straight line, called the atmospheric line, on the paper of the drum. This line is of the greatest importance for the value of the indicator diagram, as it is the reference line that shows how high, or how low, the steam pressure in the engine cylinder rises or falls, above or below the atmospheric pressure. By the varying pressures, high in one stroke and low in the return stroke, the pencil will describe the figure of the normal indicator diagram, which shows, more or less accurately, the four periods of the steam distribution—admission, expansion, exhaust and compression.

FIG. 188.—Specially Small Piston and Cylinder End for Indicator, shown in Fig. 187. The lettering is referred to in that figure.

681. How are the indicator cards taken?

For the taking of cards, the indicator is first fitted with a spring that will result in a diagram about 2 to 2½ inches high. Too strong a spring will result in too shallow a diagram, which would not allow the difference in pressure to be measured accurately.

Too weak a spring may result in a complete closing of the

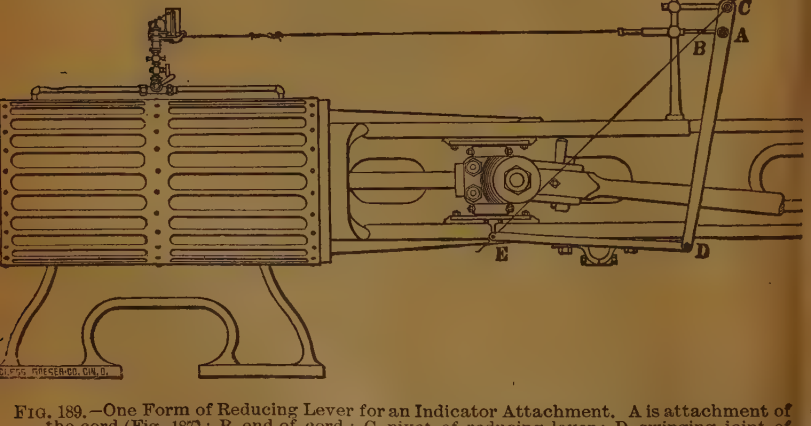


FIG. 189.—One Form of Reducing Lever for an Indicator Attachment. A is attachment of the cord (Fig. 187); B, end of cord; C, pivot of reducing lever; D, swinging joint of reducing lever; E, point of attachment to cross-head for the link joining reducing lever at D. The indicator is shown at top of cylinder, connected by a three-way cock to pipes from both ends of cylinder.

coils and no pressure indication. The momentum of the piston, also, is, with weak springs, often too pronounced, resulting in incorrect or indistinct outlines in the diagram. Particularly with a high number of revolutions, it is better to have too strong a spring than one too weak.

The indicator is screwed into the socket in such position that the point where the cord leaves the guiding pulley will be exactly above the point where it is attached to the reducing gear. The cord must be adjusted to the right length

to prevent the revolving drum from striking the stops at either end.

A little slide is often fitted, therefore, to allow a loop in the cord to be made longer or shorter, until the drum is revolved centrally between the stops.

The cord is in two pieces, one shorter piece coiling around the groove of the drum with a hook in the end, while the longer one, connecting to the reducing gear, bears the adjustable loop on the end into which the hook catches.

The card is fitted on the drum by bending it in form of a loop, hooking each end under the nearest vertical clip and push-

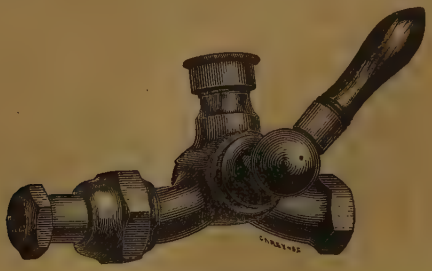


FIG. 190.—Three-way Cock for Connecting Indicator to either end of the steam cylinder, as desired.

ing it down on the drum. By drawing tight and folding the ends down sharply over the clips, the card is smoothly stretched over the barrel, so as to revolve with it. The drum cord is now connected by the hook to the cord from the reducing gear, and the card is ready for the reception of the diagram.

To obtain as true a record as possible, the pipe connections are all blown free from dirt, obstructions and condensed water with the help of the cock next to the indicator.

The working barrel and piston is well warmed up, during several strokes of the engine, before the pencil is gently pushed against the paper for the desired record.

With the usual three-way cock, the record from one end of the cylinder can quickly follow the record from the other end, directly after which the atmospheric line is drawn by opening the indicator cock to the air. This latter operation should never be forgotten and is better done after the cards are taken for the reason that the accuracy of the diagrams will be the highest when all of them are taken at practically the same temperature.

682. How is the indicator prepared for the production of satisfactory cards?

For satisfactory records, the indicator must be in the very best working condition.

All joints should work easily, but without loss of motion

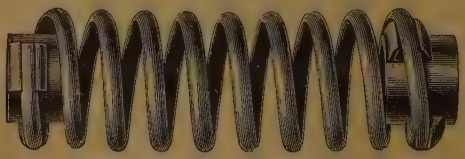


FIG. 191.—Indicator Spring, arranged for fitting into indicator cylinder.

They are best oiled before use with a fine non-gumming oil, the best neat's foot oil frequently being employed. The piston should fit tightly in the barrel without sticking. A good test is to close the bottom inlet with one finger and draw up the piston, thus creating a partial vacuum under it.

If upon releasing it goes back quickly and smartly, without sticking, good tightness without excessive friction is shown thereby.

683. What facts must be noted in connection with the indicator diagrams?

The data needed for a complete interpretation of the indicator diagrams are:

(1.) Size, name and end of cylinder to which each card belongs.

(2.) The scale of the spring that has been used.

(3.) The number of revolutions per minute.

(4.) The pressure from the steam and receiver gauges and the vacuum.

(5.) Degree of opening of throttle.

(6.) Time, date, cut-off of cylinder and other details, as desired.

684. What information can be obtained from the indicator diagram?

The information obtained from the indicator diagram is:

(1.) The mean effective pressure (M. E. P.) per square inch, which is used for determination of the indicated horse-power developed in the corresponding cylinder. If the mean effective pressure per square inch is multiplied by the area of the piston, the total pressure on the piston is obtained.

If this total pressure is multiplied by the piston speed per minute, as already described, the result is the power developed in one minute and expressed in foot pounds. To express this in terms of horse-power, it must be divided by 33,000, which is the equivalent in foot pounds per minute to one horse-power.

(2.) The time and extent of each period of steam distribution and the rapidity of opening or closing the ports for the commencement or end of these periods.

(3.) The highest steam pressure during admission and the lowest during exhaust.

(4.) The uniformity of pressure during admission and exhaust, and the regularity of variation of the pressure during expansion and compression.

685. How is the mean effective pressure found from th indicator diagram?

The mean effective pressure is found from the indicato diagram by dividing the length of the diagram, which repre sents the stroke, into an equal number of parts, each sma enough to allow its mean ordinate, or pressure, to be used as rep resenting the whole part. By adding the mean ordinates c

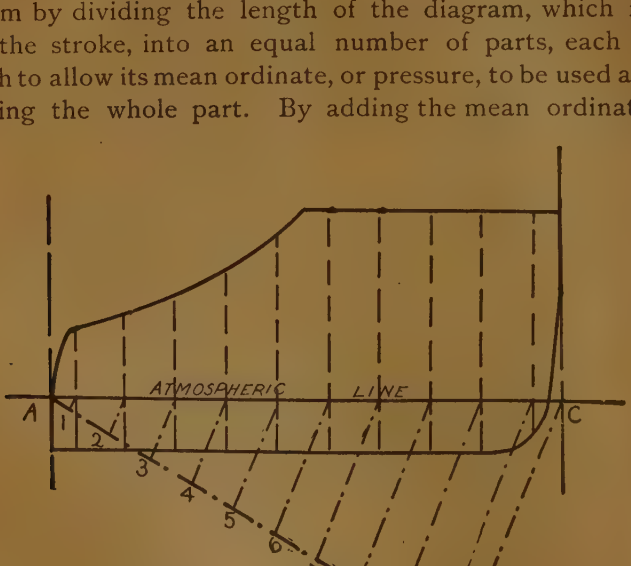


Fig. 192.—Ideal Indicator Card, showing process of estimating by ordinates. (Sections 685, 686.)

these parts together and dividing the sum by the number parts, a mean ordinate, or pressure, is found for the whole di gram, which is used for the determination of the horse-powe One method frequently employed for measuring indicat diagrams is as follows:

On Fig. 192, which represents the card to be figured up, firs two lines are drawn, touching the diagrams at the ends ar standing square on the atmospheric line. On a slanting lir

starting at the intersection, A, of the atmospheric line and the vertical line, a scale is constructed that helps to find the desired ten subdivisions on the length of the diagram, and on which the mean height of each tenth is to be measured.

The scale on the slanting line, starting from the point of intersection, A, may be made by setting off, first, $\frac{1}{4}$ inch, then, nine times, $\frac{1}{2}$ inch, and, finally, again $\frac{1}{4}$ inch, thus making the whole scale five inches long. The end point, B, of this scale is connected by a straight line with the intersection, C, of the atmospheric line, and the second vertical line and lines parallel to BC are drawn through all the other ten points of the scale, until they intersect with the atmospheric line. After drawing vertical lines through all these intersecting points, the ten mean ordinates, or pressures, can be measured, each individually, or in a convenient way, as a sum total, by taking the mean ordinates off continuously upon a strip of paper. If this sum total is divided by ten the mean for the whole diagram is found.

Another method is to use a planimeter for finding the total area of the figure in square inches. If this area is divided by the length of the diagram in inches, the mean height in inches is obtained, which is equivalent to pressure, read in the scale of the spring.

686. How is the time and extent of the periods of steam distribution shown in the indicator diagram?

The time and extent of the periods of steam distribution is marked most clearly on the theoretical indicator diagram, Fig. 192, to which the real diagram should conform as closely as possible. As seen in this diagram, the steam must have already attained its full pressure when the piston commences its stroke. The line of admission pressure remains, as nearly as possible, straight and parallel to the atmospheric line, until the point of cut-off is reached, when the line gradually falls in the form of a smooth, fair curve.

Shortly before the end of the stroke a new turn occurs, which brings the line quickly down to the exhaust, at about the end of the stroke.

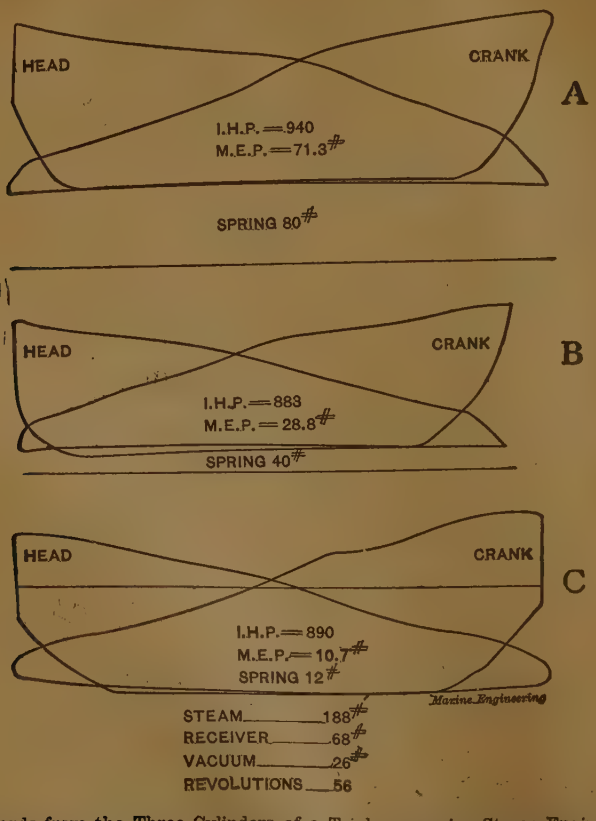


FIG. 193.—Cards from the Three Cylinders of a Triple-expansion Steam Engine, giving data relating to horse-power, mean effective pressure, spring tension of indicator, etc A is the card from the high-pressure cylinder, B, from the intermediate pressure C, from the low-pressure.

The exhaust line remains straight and parallel to the atmospheric line until the closing of the port for compression. At this point the line turns upward in the form of a smooth curve

FIG. 194.—Series of Indicator Cards, taken from the engines of the lake steamer "City of Erie," during a race with the steamer "Tashmoo," showing variations in pressure indicated horse-power, revolutions per minute, etc.

until the lead opens the port to the admission pressure by a quick rise to the full height at the commencement of the new stroke. This lead, as well as the advance opening to the exhaust after expansion, need be, and should be, no more than sufficient to secure and maintain uniformity of admission and exhaust pressure upon the piston.

687. How is the rapidity of the opening and closing of the ports shown in the indicator diagram?

The rapidity of the opening and closing of the ports is shown in the diagram by sharp corners for quick opening with little wire-drawing, while round corners indicate slow opening with considerable wire-drawing.

688. What is indicated by the highest point in the admission pressure line and by the lowest point in the exhaust pressure line?

By measuring on the scale of the spring the highest admission pressure it is possible to obtain, by comparison with the gauge pressure, the drop through condensation, or loss of pressure, by contraction of ports or pipes. By comparing the lowest pressure of the exhaust line with the vacuum, an idea may be formed of the condition of the exhaust ports and pipes as to whether they allow a free and unobstructed exhaust.

689. What is indicated by straight admission and exhaust lines?

If the admission and exhaust lines are straight and parallel to the atmospheric line, sufficiently large ports are indicated through which the steam can pass without throttling or wire drawing. Another conclusion to be drawn from such straight lines is that the piston and the valve are tight enough to prevent effectively all interchange of the admission and exhaust steam.

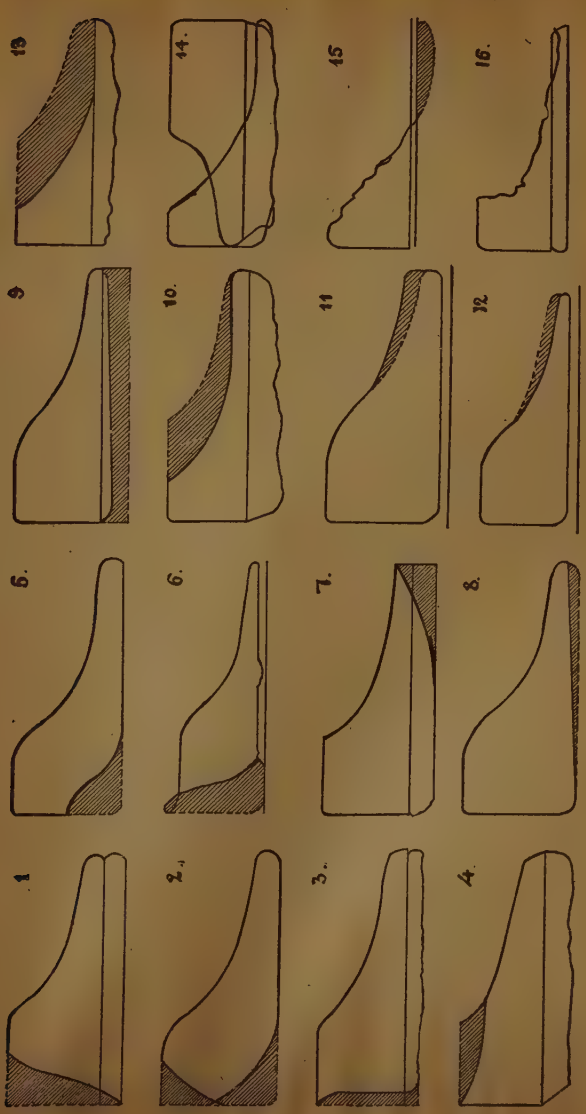


FIG. 195.—Series of Indicator Cards, showing various conditions of lost power, as explained in accompanying sections.

A straight admission line also indicates dry steam, and little or no condensation, during the movement of the piston.

690. How is regularity of variation of the pressure during expansion and compression indicated in the diagram?

The variation of pressure during expansion and compression is shown to be regular and effective by the form of the curve in Fig. 195, which falls, with gradually decreasing rapidity, for the expansion, while rising, with gradually increasing rapidity, for the compression, until the curves come to the point of advance opening of the port.

From this point the expansion line falls to the exhaust, while the compression line rises to the admission, both with increasing rapidity.

691. What irregularities of the steam distribution are frequently observed through indicator diagrams?

The irregularities of the steam distribution, frequently observed through indicator diagrams, may extend to top and bottom cards, or may be observed only in one card. How much power may be lost by such irregularities is shown by the shaded parts of the diagrams on Fig. 195.

Engines of the vertical screw type with valve gear, which influences admission and exhaust from one eccentric, show the irregularities generally also in these two directions; while beam engine valve gears, with independent operation of the steam and exhaust valves, will show the irregularities more locally.

692. What irregularities of the admission are observed?

The irregularities of the admission may be:

(1.) Lead is too early or too late.

(2.) Admission is too short or too long.

(3.) Admission line is falling rapidly before cut-off.

(4.) Admission line is rising and falling irregularly.

693. What is indicated by a faulty lead?

If too early a lead occurs in top and bottom card, it indicates too large an angle of advance of the eccentric; in the same manner too late a lead, or none at all, in both cards indicates too small an angle of advance of the eccentric. If an early lead on one end is combined with a late lead, or none at all, on the other end, generally the valve stem is either too short or too long, and the valve will have to be raised or lowered.

The lead may also be affected by the size of the steam lap. Too small a steam lap will produce a large or early lead, while too large a steam lap may produce a small or late lead.

It should be remembered that the lap and the angular advance both are responsible for the lead and the same measurements taken for valve-setting are best consulted, in addition to the diagram, for the final decision on the alterations intended to produce a satisfactory steam distribution.

694. What is indicated by a faulty length of the admission line?

A faulty length of the admission line is due to a faulty angular advance of the eccentric, if occurring in both cards simultaneously, while it is due to faulty length of the valve stem, if one card shows a perceptibly longer admission line than the other.

695. What is indicated by a rapid falling of the admission line before cut-off?

A rapid falling of the admission line may result from condensation of the steam as soon as it enters the cylinder. This takes place, to some extent, in all cylinders, but is much more pronounced when the lagging of the cylinder is insufficient, or when the range of expansion, or range of temperatures, is very

large, as is often seen in the high-pressure cylinder of multiple expansion engines, working with high boiler pressure.

Another reason for the falling of the admission line may b too small an area of the ports or of the steam-pipe. The stean cannot follow the piston quickly enough, with a consequen reduction of the pressure in the cylinder. Sometimes th ports are not opened sufficiently by the valve, and this occur mainly in cases where the steam laps are too large, in propor tion to the stroke of the valve.

A leaky piston may be the cause of a pronounced fall in th admission pressure, and a consequent increase in the exhaus pressure of the other card, if the leakage is very pronounced

696. What is indicated by an irregular rising and falling o the admission line?

An irregular quick rising and falling indicates jerky mo tions of the indicator piston, due to a spring that is not suite to the pressure, to sticking of the piston, or to water in the ind cator pipes. The remedy would be to fit another spring, t take out the piston of the indicator for cleaning and oiling, an to blow out the pipe connections thoroughly.

With multiple-cylinder engines it is practically impossibl to get straight admission and exhaust lines for the interme diate and low-pressure cylinders, as the limited capacity of th receivers will produce considerable fluctuation in the pressure

697. What irregularities are observed in the expansio line?

The irregularities of the expansion may be:

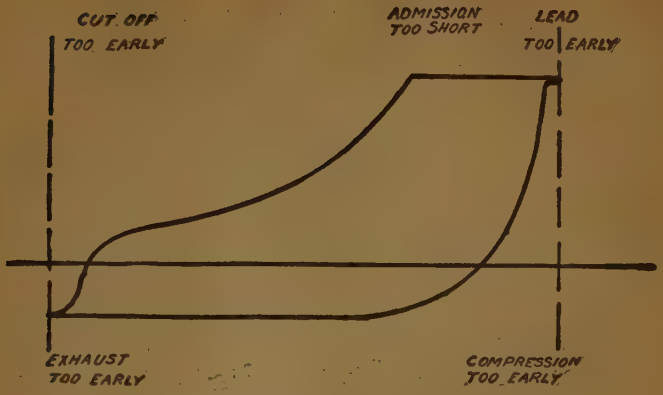
(1.) Cut-off is too early or too late.

(2.) Exhaust lead is too early or too late.

(3.) Curve is of faulty form.

698. What is indicated by a faulty cut-off?

A faulty cut-off may be too late or too early, and due t



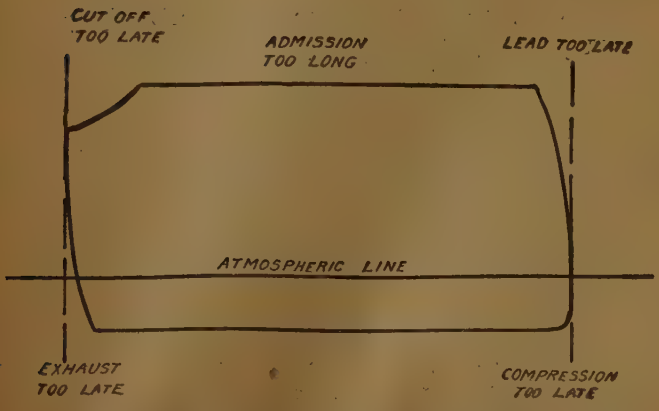


FIG. 196.—Sample Indicator Cards, showing undesirable valve settings.

too small or too large a steam lap, aside from the influence th may be exercised by the angular advance of the eccentric.

If the steam lap is too small, a late cut-off will take plac while with a steam lap that is too large an early cut-off w occur.

699. What is indicated by a faulty exhaust lead ?

The exhaust lead may be too early, and thus allow t pressure to drop to the exhaust line before the piston has co to the end of its stroke. If it is too late, the steam cannot g out and a back pressure and loss of power will be the result.

700. What is indicated by a curve that is of faulty form ?

A curve of faulty form may indicate leakage through t valve, when the curve does not fall quickly enough after cu off, but rather remains near, or returns to the admission pres ure. The card indicates, thus, an excessive steam consum tion and small economy.

701. What irregularities are observed in the exhaust line

Aside from those due to undesirable exhaust lead the regularities of the exhaust line frequently shown are :

(1.) Falling and rising of the line.

(2.) Too early or too late a compression.

702. What is indicated by falling and rising of the exhau line ?

Falling and rising of the exhaust line may be due to eith of two causes:

(1.) The exhaust ports or pipes may be contracted, so not to allow the steam to pass out as rapidly as it is displac by the piston at its greatest velocity, thus creating a certa back pressure toward the middle of the stroke.

(2.) The other reason may be that either the piston or t valve leaks, allowing live steam to enter, and thereby raise t pressure.

The quick, jerky movements of the indicator piston, as may occur in the admission line, are rarely seen in the exhaust line, as the probability of the influence of water is remote, and the downward stroke of the indicator piston is small, therefore not producing much momentum.

703. What is indicated by too early or too late a compression?

Too early a compression indicates too large a lap, due to a wrong length of valve stem, if the card from the other end shows too small a compression. It may also indicate too large an angular advance of the eccentric, if both cards show the same irregularity, and, in either case, it is associated with a large lead.

Lap and angular advance together may also contribute to the same result, and the measurements of valve-setting will most clearly indicate where the fault lies. Too late a compression is due to too small a lap, to too small an angular advance, or to both.

704. What irregularities may be observed in the compression line?

A normal compression line, being generally short, shows any irregularity probably only in the case of leakage, due either to imperfect fit of the piston or the valve. With slide valves, a jumping from the seat may occur, due to excessive compression, poorly balanced valve surface, or to weak holding-down springs.

705. At what other places can the indicator be applied?

The indicator can be applied with advantage to the

(1.) Main steam pipe.

(2.) Valve chests or receivers.

(3.) Exhaust pipe or condenser.

(4.) Air pump, feed pump and other pumps.

706. What information is gained by an indicator diagram from the main steam pipe, valve chests or receivers?

Diagrams from the main steam pipe and the valve chests show whether or not contraction of the passages leads to throttling of the steam, while those from the receivers show the fluctuations of the steam pressure.

707. What information is gained by a diagram from the exhaust pipe or from the condenser?

Diagrams from the exhaust pipe or condenser show, by comparison with the exhaust line, from the cylinder diagram, whether or not any back pressure results from contraction of

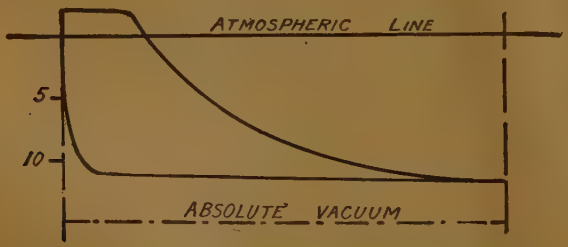


FIG. 197.—Indicator Diagram from an Air Pump.

the passage; thus establishing the causes for any irregularities in the exhaust line more clearly.

708. What information is gained by diagrams from air feed or other pumps?

Diagrams from the water cylinders of air, feed, bilge and other pumps show clearly how the automatic valves act; when they close; if they remain tight during the stroke; when they reverse, and how quickly the change from discharge to suction pressure takes place. They are highly instructive, also, as showing how a smooth and uniform working can be produced by well-placed air vessels, and how the admission of air by pet cocks affects the pressure exercised by the pump piston.

The tightness of the piston stuffing-boxes and internal and external joints is subjected to a searching criticism by an indicator diagram. If diagrams from steam and pump cylinders of the same pump are taken, an idea may be formed of how much power is consumed by the friction of the pump.

Diagrams from the suction and discharge pipes indicate the fluctuations in the pressure, and can be made of use in locating water-hammer, as well as in suggesting its remedy, in the form of judiciously-placed air vessels.

709. How is the indicator connected when used for taking diagrams from pipes or pumps?

The indicator, when used for taking diagrams from pipes, derives the motion for its paper drum from the cross-head or piston rod of the cylinder, to or from which the pipe leads. For pumps, the respective piston rod or cross-head moves the drum.

For all water connections, the indicator should be attached horizontally, to prevent any air from getting under the indicator piston. The air would provide an elastic cushion, which would prevent clear indications of the fluctuations of the pressure or water-hammer. As the water strikes the piston, often quite hard, a rather stiff spring is generally chosen to make sure that the coils of the spring are never totally closed through the impact upon the indicator piston.

710. How is it possible to learn the amount of feed water used by the engine?

The amount of feed water that goes into the boiler may be measured by a water meter, or the pump may draw its supply from a graduated tank.

Water meters, while not absolutely correct, need not vary in accuracy more than from 1 to 3 per cent., and, if checked by

graduated tanks, can furnish the engineer with fairly accurate information as to how much water is evaporated by the boiler.

Tanks provide a very good means of ascertaining the feed-water supply, if fitted with water gauges and indicating marks at different heights, between which the capacity of the tank is known. The readings in the middle parts of the tanks are more nearly correct, where the area of the water surface is large and uniform.

There is less uniformity at the top and bottom, and hence more difficulty in the observation of the variation in the water level. Where there are several tanks, it is generally quite convenient to draw from a particular tank for a certain length of time, and thus get an indication of how much water is supplied, with everything as near to the average working condition as possible.

It is necessary to make absolutely sure that all the water drawn off by the pump is forced into the boiler, and does not escape through leaks or other outlets.

If the number and average length of strokes of the feed pump are determined for the same time, a factor of efficiency can be found for it which tells how well the pump does its work.

711. What other factor is it desirable to know at the same time?

Another factor that is desirable to know, outside of indicator cards and feed-water consumption, is the amount of coal consumed during a certain length of time.

The coal may be weighed when it comes in buckets from the bunkers, or, for a rougher estimate, the bucketfuls may be counted, after determining the weight of an average bucket.

712. What conclusions can be drawn from the knowledge of these factors?

From the knowledge of the coal consumption and the water supply or steam evaporation, a conclusion can be drawn, as to how efficiently the boiler does its work of steam evaporation and whether it realizes such average evaporation as mentioned in Section 115.

From the knowledge of the steam evaporation and the indicated horse-power in the main engine and all independent auxiliaries, a conclusion can be drawn as to how efficiently the engine has transformed the heat of the steam into work and if it realizes such average steam consumption per indicated horse-power as mentioned in Section 119. It is necessary that the evaporator should not be used during the time of test and that the safety valves and the whistle should not be operated.

713. What information can be derived from taking temperature readings?

Taking the temperatures of steam and water in the different cylinders, pipes and vessels can indicate quite accurately how efficiently these fluids perform their duty.

714. Where are such temperature readings most desirable?

Readings of the temperature are most desirable, first, at the main steam pipe, the receivers, the exhaust pipe or the condenser; further at the air-pump suction, at the inlet and the outlet of the condensing water into the water chests; at the suction of the feed pump, and if a feed heater is fitted, also at or near the check valve in the feed water delivery pipe.

715. What information is gained from the reading of the thermometer at the steam pipes?

The temperature of the steam is intimately related to the pressure, as stated in Section 86.

It may be concluded that the steam, at its temperature of saturation, is inclined to precipitate considerable water, and lower its pressure, if only slightly cooled; while it will retain its pressure and dryness well, if the temperature shows a certain degree of superheating.

Through the reading of the temperature, a rapid lowering of the admission line in the indicator diagram can often be very clearly explained. At the same time, better lagging may be indicated as a remedy for better retaining of the heat and lessening of the initial condensation.

716. What information is gained by the reading of the thermometer at the condenser?

The temperature of the condenser may prove of value in finding the cause of an imperfect vacuum. If the temperature of the exhaust steam is high, a deficient supply of condensing water may be the cause of the lacking vacuum; while, if the temperatures of the exhaust steam and at the air-pump suction prove to be normal, air leaks will, in all probability, be the cause of the trouble.

The air pump, in each case, must be proved to be in good condition by indicator diagrams.

717. What information is gained by the reading of the thermometer at the air-pump suction?

The temperature of the water at the air-pump suction may indicate an excess, or deficiency, in the amount of cooling water.

The water in the bottom of the condenser should not fall below from 110 to 130 degrees Fahrenheit, as it is to be used for feed water, and should possess, for this purpose, as high a temperature as possible. The reason for too cool a feed water may however, lie not only in an excess of cooling water, but also in the arrangement of the cooling surface.

The tubes should leave a certain space in the bottom of the condenser, where the water may collect between the strokes of the air pump and thus be free from the cooling influence of the tubes.

718. What information may be derived from the reading of the thermometer at the inlet and outlet of the cooling water?

The reading of the thermometer at the inlet and outlet of the cooling water tells, by the difference, how much heat is abstracted from the steam by the cooling water. As it is not desirable to heat the cooling water above from 95 to 100 degrees Fahrenheit, the water is kept in contact with the tubes until this temperature is reached. Cold water, therefore, should travel more slowly over the cooling surface than warm water. With an independent circulating pump, or with injection condensers, the supply of condensing water may be adjusted until that temperature at the outlet is realized which proves most efficient for the performance of the engine.

719. What information is gained from the reading of the thermometer at the feed pipe?

The amount of additional heat that must be supplied to the water, for its conversion into steam, can be determined by the temperature of the feed water, as found at the hot well, or at the inlet to the suction pipe. If a feed heater is fitted, a reading of the temperature will tell how much additional heat has been imparted therein to the water, and will, thus, be available for steam generation in the boiler.

720. What other means are employed by the engineer for indication of the efficient working of the machinery?

Pressure gauges are ready and rapid means for helping the engineer to inform himself about the working of the engine.

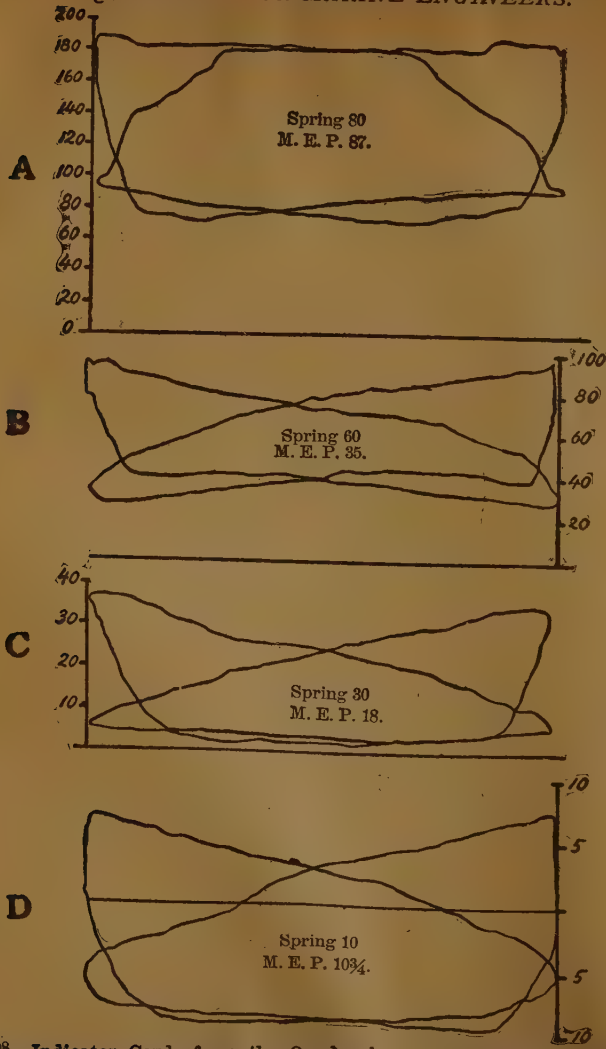


FIG. 198.—Indicator Cards from the Quadruple-expansion Engine of the Steamer "Wilkes-Barre." In this test steam pressure is 200 lbs.; vacuum, 22 inches; R. P. M., 84.79.

A is the card of the H. Pr. Cylinder, showing 516 H. P.
B " " " 1st I. Pr. " " 441 "
C " " " 2d I. Pr. " " 481 "
D " " " L. Pr. " " 623 "
Total H. P.=2,061. Ref. M. E. P.=36.8 lbs.

Gauges may often indicate trouble in the same manner as indicator cards and with much less labor.

The receiver pressures, as told by the gauges, may indicate to an engineer familiar with the engine whether it is advisable to link up one or the other valve gear, for more uniform distribution of the power between the cranks.

The reading of the vacuum gauge may help in the work of adjusting independent air and circulating pumps to the lowest number of revolutions and the least steam consumption capable of producing the desired degree of vacuum.

Pressure gauges that are connected with the water cylinders of the pumps may, by their fluctuations, give a fairly good idea of how the pump performs its work, if the suction is good, or if air leaks impair its power.

721. How is observation of the engine's operation carried out?

The observation of the working of the engine is carried out in a systematic manner by visiting and inspecting at regular intervals all the working parts; by oiling the bearings; by reading the gauges, revolution counters, thermometers and the water meter; by taking indicator cards; by checking the coal and entering the record at stated times in the log book.

The log book furnishes in its record a history of the performance of the engine, from which, in comparison with former performances, a clear judgment of the last one may be gained.

A careful engineer will never neglect to establish and continue such a record, which enables him to prove to himself, and others, that the machinery plant under his charge is always in the safest and most profitable condition.

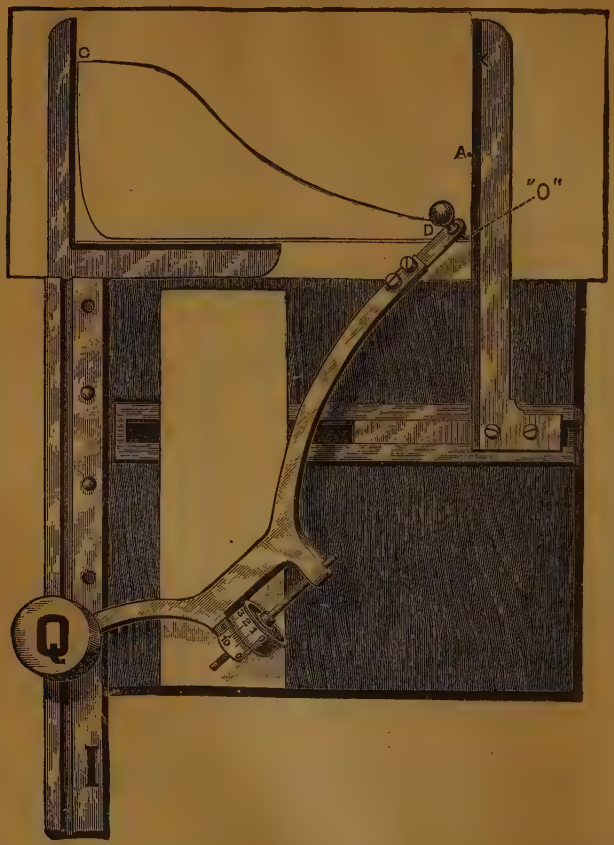
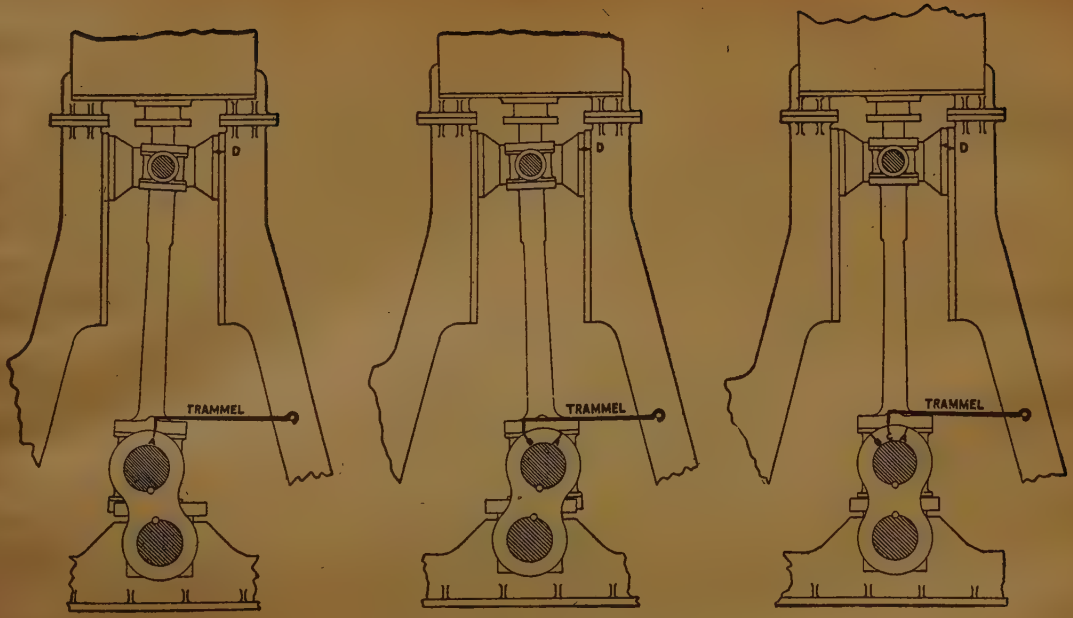


FIG. 199.—Method of Averaging a Diagram with one Type of Planimeter. The Pin, Q, is set in the groove, I. The card is held on the board between clamps C and A. The tracing point, O, is set at point, D, and the arm moved clockwise, the vernier and drum having been set at zero. The drum measures squares inches and tenth-inches, the vernier hundredth-inches. If, after the tracing point has circumscribed the diagram, the drum shows 2 inches and 6-tenths, and the vernier 4 beyond the last graduation on the drum, the area of the diagram will be 2.64 inches. This result is then divided by the extreme length of the diagram, to give the average height, and the quotient multiplied by the number of the indicator spring used in making the card, in order to find the M. E. P.

PART EIGHT.

BREAKDOWNS AND REPAIRS.

CHAPTER TWENTY-SIX—COMMON BREAKDOWNS AND REPAIRS.



How to find the Dead Center

To put the crank on the top center, first turn the engine up to near the top, and mark the guide and shoe at D; then with a trammel fixed on the column, and long enough to reach the crank, mark the top of the crank at A. Now turn the engine over the center until the marks on the guide and shoe come together again at D, and again mark the crank top with the trammel at B. Find the center between the two marks on the top of the crank, and make a mark C, and turn the engine until the mark C, comes in line with the trammel point. The engine will then be on the top center. The crank is put on the bottom center by the same method, the trammel being applied to the bottom end of the crank instead of the top.

CHAPTER TWENTY-SIX.

BREAKDOWNS AND REPAIRS IN MARINE MACHINERY.

722. What breakdowns are most likely to occur in the boiler?

The breakdowns most likely to occur in the boiler are cracks in the plates, bulges in the heating surfaces, split or leaky tubes, stay bolts or braces, and defective fittings.

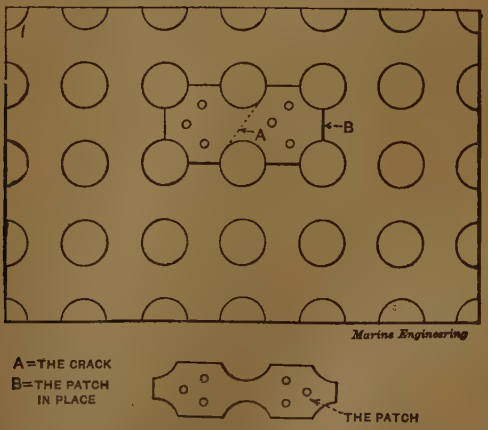


FIG. 200.—Diagram showing a Convenient Method of Repairing a Cracked Tube Sheet. A patch, such as is shown at base of the cut, is shaped to fit neatly over the crack and between the tube ends. After smearing both surfaces with red lead, it is secured in place by tap bolts.

723. What remedies are applied to cracked plates?

Cracks in the boiler material may be shown to be due to original defects of the material, to faulty methods in the manufacture or to excessive local strains. They may show around

rivet holes, at flanged corners or between tube openings, although these accidents are seldom found in modern boilers.

If the leakage from the cracks is large, the boiler must be placed out of service, blown down and cooled until it is possible to enter and make repairs. If possible the cracks should be drilled off at the ends by small holes, which will prevent further extension, and patches put over them, either on the inside or on the outside. If riveting and caulking of the patches is not practicable, bolting must be resorted to, for holding them down. The so-called boiler patch bolt, which screws through the plate against a conical head, proves much more efficient for a tight joint than a common bolt. The patches are put on with a good fit and the interstices completely filled with red lead, putty or iron-rust cement.

724. What remedies are applied to bulges in the heating surface?

If the bulges in the heating surface are not very large, and the surrounding stays or braces prove all sound and well fitted, no special remedy may be required, apart from careful and frequent inspection and measuring with templates. Where the bulges are large and the stay bolts, or braces, are torn out of the plate, or ruptured, staying must be resorted to. Such staying generally proves preferable to any attempts to force the surface back into its original form. The number of stay bolts is preferably increased with closer spacing in new positions.

A bulge may occasionally occur, in consequence of a rupture of one of the old large braces. In such a case it proves advantageous to employ a heavy girder plate that takes the repaired brace in the centre, and a number of screw stay-bolts around its circumference. The stay bolts are conveniently tapped and riveted into the material, while a plug closes the old brace hole. The connection to the old shortened brace

may be effected by a cross-key behind the girder plate. This repair leaves the plate effectively exposed to the cooling circulation of the water.

If the bulged plate is not in convenient reach from rigid parts of the boiler for stay-bolt connection, girders may be resorted to. The girders should extend well over the nearest rigid points of attachment, and support the plate by numerous carrying bolts. Good clearance under the girder will insure active circulation and avoid further over-heating. Bulged cir-

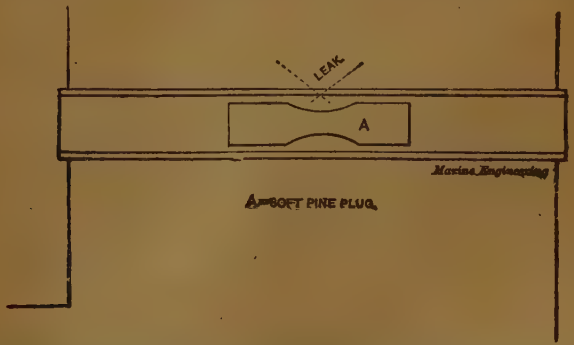


FIG. 201.—Sectional Diagram Showing an Easy Method of Repairing a Leaky Boiler Flue. A plug, shaped as at A, is pushed into the flue until it reaches the point of leakage, where the escaping steam and water cause it to swell, thus stopping the leak.

cular furnaces, if not altogether collapsed, can be put in such condition that they will safely carry a reduced steam pressure, by closely spaced circular rings of angle or bar iron, fitted in halves. When only one boiler is carried in the ship, it may be of the utmost importance to place it in the position of generating steam of, at least, reduced pressure.

725. What remedies are applied to split or leaky tubes, stay bolts or braces?

Split tubes are repaired by plugging.

In fire-tube boilers, this is accomplished, in temporary form,

by a soft wooden plug, which is driven into the tube until i covers the split. The water leaking through swells the plug and by pressing tightly against the side of the tube, it then pre vents further escape of water.

A more permanent form, employed where there is seriou leakage, is the tube-stopper, containing two conical cast-iro plugs, fitted with metal packing in the tube ends, and draw up tight by the nuts of a through bolt.

In order to apply the tube-stopper, the fires must be draw

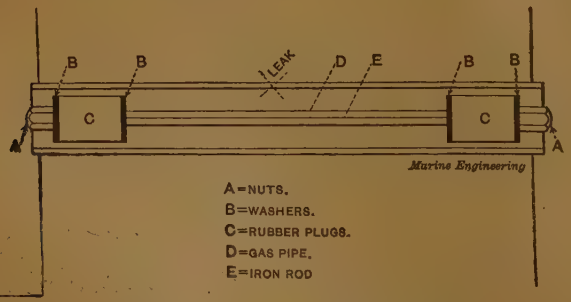


FIG. 202.—Emergency Device for Stopping a Leaky Boiler Flue. An iron rod, having a thread at both ends, is fitted with a nut, A. A washer, B, is then put o then a rubber plug, C, another washer, C, and a length of gas-pipe against th second washer. The opposite end of the rod, E, is similarly fitted, after which th act of screwing up the nuts causes the rubber plugs to bulge, filling the tube.

and a man allowed to enter the combustion chamber to inse the plug.

Another form of tube-stopper, which can be inserted e tirely through the uptake doors (Fig. 202), consists of two heav rubber washers between two pairs of plate discs. The two i side discs are spaced and held apart by a piece of gas-pip while the outside ones can be drawn together by the nuts on central bolt, thereby compressing and spreading the washe until they bear tightly against the side of the tube and st the leakage.

With water-tube boilers, the repair is more difficult, as t

fires must be drawn and the water blown down. It is also much more difficult to locate the split tube.

Leakage around tube ends may be due to too much forcing of the draft and can often be remedied by checking the draft. If the tubes are loose, re-expanding is resorted to until tight, or at least until they show only small leakage.

Leaky stay bolts and braces can often be cured by putting a grummet and plenty of putty under the nut.

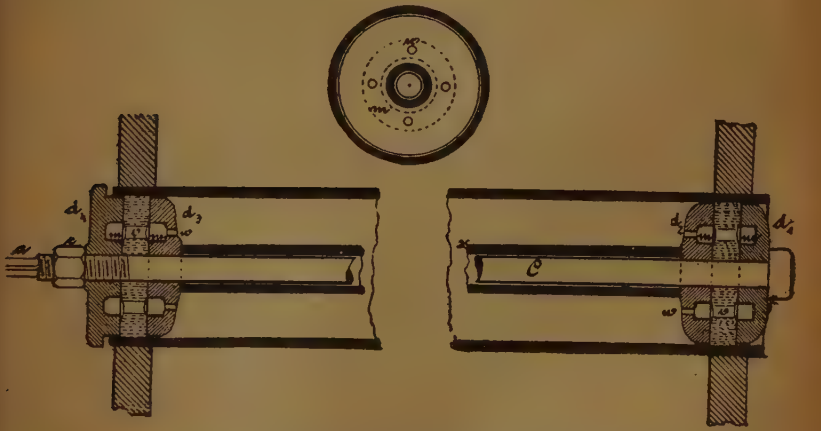


FIG. 203.—Form of Rubber Tube Stopper, similar to that shown in Fig. 202. Here c is the threaded end of the iron rod, c; e, the nut; d^1, d^2, d^3, d^4, washers; D and D, rubber discs; x, the iron gas-pipe; m, m, holes in the washers, open at w and w.

726. In what parts are defective fittings mostly found?

Aside from minor defects with water gauges, test cocks and steam gauges, manholes and furnace fittings, most defects in the fittings occur with the safety valves, check valves, steam stop valves and blow valves.

727. What defects occur in safety valves, and how are they repaired?

The safety valve may be broken, which fact will be shown

by steam escaping through the escape pipe. Nothing can be done until it is all gone. In case the valve itself, or the spindle, is broken, sometimes a new valve can be built by fitting a disc of heavy plate into which a stem is riveted in the centre.

If the spring gives out and no spare one is on hand, it may be possible to fit a long lever, pressing on the spindle of the valve and load it at the end with sufficient weight to hold the normal pressure. Where room permits, lead discs may be cast and placed on the spindle and the valve thus loaded.

In case the valve is jammed and does not blow off with a rapidly rising steam pressure, the valve may be given a sharp blow, which sometimes will start it. If this does not produce the desired relief, all steam outlets to auxiliaries and condenser must be turned on full, to work off the steam. Fire and uptake doors are better opened and the fires deadened with wet ashes, until well within the working pressure.

The steam is better allowed to fall until it is possible to dismount the valve and refit it in efficient condition.

728. What defects occur in the check valves and how are they repaired?

The defects in check valves are usually due to breaking or jamming. Indications of defects are given by the absence of the click, generally quite noticeable in check valves, and by the valve becoming hot from the boiler water, at least in cases where the feed water is not heated before entering the boiler.

With a broken valve, it will usually be necessary to turn on the auxiliary feed supply, close the cock or valve between boiler and check and replace the broken valve by a spare one, if on hand, or by such a makeshift as can best be built with the available resources. With a jammed valve, a smart tap with a hammer or tool sometimes jars the valve loose, other-

wise it has to be taken out and refitted with more clearance of the wings, or by straightening the stem, or by removing the disturbing cause.

Such repairs should be effected as soon as time allows, in order to have always two arrangements for feeding in good working condition.

729. What defects occur in the steam stop valves, and how are they repaired?

The defects in steam stop valves occur most frequently in the valve, its seat, the spindle, the cover or the yoke of the valve.

In serious fractures it will be necessary to cut off the affected boiler and relieve it of its steam by deadening and drawing the fires and working the steam off, until it is possible to open and repair the valve. If the steam escapes from it in large volumes, so that the fire-room must be abandoned, the last thought should be to deaden the fire and prevent rising of the pressure, by opening the furnace doors and keeping the feed pump going, in order to prevent low water under the enforced lack of attendance.

The repairs will extend to the replacing of the broken parts by spares, or emergency, parts. If the covers are broken, bolted patches of wrought-iron bar or plate, put on with cement or putty, may be resorted to.

730. What accidents may occur to blow valves, and what are the remedies?

The accidents to the blow valves may extend to the valve and its spindle, or to parts of the valve casing.

Cocks are, comparatively speaking, simpler, and accidents to them occur generally to the casing, flanges or bolt connections. Where only internal parts are broken and no water or steam escapes to the fire-room, it may be considered safe to

rely upon the outboard blow valves and their tightness, but the greatest vigilance must be exercised to guard against any loss of water or steam by leakage.

Injury to the outside casings, particularly the casing of the bottom blow valve, may result from heavy objects falling upon the valves; floor plates may work loose and knock against the valve, under the movements of the ship. Many engineers prefer to have the bottom blow valve well above the fire-room floor in plain sight and out of reach of possible injury. If the water or steam escapes in large volumes, nothing remains but to abandon the fire-room, but, if possible, the fire should first be drawn, the furnace doors opened and the feed put on with full force.

The most imminent danger, with broken bottom blow valves, is the possibility that the rapidly falling water level will leave the heating surface exposed to overheating and consequent collapse. The attempt should be made, under all circumstances, to get the fires out of the affected boiler before abandoning it.

The necessary repairs consist in patching the broken body or its flanges; drilling new bolt-holes, and fitting more and stronger bolts, if desirable. Sometimes a valve of about the same size can be taken from a less important place and substituted for the broken one.

If there is danger of recurrence of external impacts, safety guards or protecting brackets, or angle bars, may be fitted around the valve.

If the breakage occurs in the valves on the shell of the ship, the opening is sometimes plugged and connection made to a neighboring sea valve.

731. What breakdowns are most likely to occur in the engine and auxiliaries?

Breakdowns may occur in the stationary parts, as cylinder

casings, liners, covers, columns, bed plates, individual bearings and stern tubes, condenser shells, auxiliary machinery, piping and fittings, which can be repaired by patching with wrought-iron bars or plates. The defects may also appear in the moving parts, as piston, piston-rod, connecting-rod, any part of the valve gear, shafting, propeller or moving parts of the auxiliaries, which sometimes can be patched, while in more serious cases complete replacing by substitutes may be necessary.

732. What defects are likely to occur in the cylinders and liners?

The cylinders and liners are most exposed to the danger of cracking by unequal expansion, or to injury by the loosening of some of the interior working parts. One mode of repair consists in drilling holes at each end of the crack, to prevent further extension; in riveting soft iron plugs into these holes, and in fitting patches over the crack with sufficient cement or putty to make a tight joint. It may be necessary to chip away ribs, flanges or bearing strips to secure a close fit of the patch on the casting. Where the thickness of the metal is sufficient for the purpose and no patch needed for strength, a dovetailed groove may be cut over the line of the crack, and a strip of copper or soft metal hammered into it, care being taken to have the caulking metal on the side of the excess pressure, if possible.

It is, fortunately, a rare occurrence to have any of the cylinder castings injured to such an extent as to be entirely beyond repair.

733. What breakdowns are likely to occur in the cylinder covers?

The injuries to the cylinder covers result, in most cases, from condensed water, loose bolts, nuts or other small parts, accidentally dropped into the clearance space. The knocking

out of the head may extend to the whole head or may show only in local cracks or holes. Particularly on the lower head, if it is part of the cylinder casting, a patch must be applied, which operation, however, is often very troublesome and laborious, especially if the fractures extend into the piston rod stuffing-box. The upper cylinder head or the heads of the piston valve chests are sometimes totally destroyed, in which cases emergency heads must be built from plates, angles or whatever material is available. Repairs have been executed where flat plates, stiffened with angles and fitted with wooden chocks for filling the excess of clearance spaces, have quite successfully kept the cylinder in operation.

With multiple-expansion engines, where the cutting-out of one cylinder does not necessarily cripple the engine, it is possible to disconnect the piston of the affected cylinder, draw it up into the opening of the broken top head and fit a ring of soft packing around it, so as to make the opening steam tight. If the connecting rod and the valve are removed, and the cross-head, piston rod and piston are securely blocked, it is possible to operate the engine successfully, although it is reduced from a compound to a single expansion or from a triple to a compound engine.

The steam blows through the empty valve chest of the injured cylinder into the next cylinder, or into the condenser. It will always be advisable to reduce the pressure, partly to ease the packing of the improvised head, partly to avoid an extra amount of work for the remaining cylinders and pistons.

734. What breakdowns are likely to occur on the columns and the bed plate?

Breakdowns and fractures of columns and bed plate seldom occur independently, but are usually the result of excessive strains by accidents to other parts of the engine. They will permit of patching, if not too extensive. Cases have occurred

where severe weakening of the columns has been supplemented and assisted by wooden struts, adjusted by wedges to take thrusting strains, while long, heavy, screwed bars and nuts have helped to sustain the tensile strains. In other cases parts of the bed plates have been held in place by wooden chock pieces, firmly wedged against bulkheads, floors or other structural members.

735. What breakdowns frequently occur in the bearings?

The bearings give trouble most frequently by becoming hot. This condition may result from insufficient lubrication, from hard foreign substances like sand, filings, emery or pieces of broken glass that get between the bearing surfaces, or from too much pressure upon either surface. In severe cases the anti-friction metal may melt out, or the shaft and the bearing metal may burn together. The remedies for this trouble should be applied at its first appearance.

Easing the cap somewhat and liberally increasing the amount of lubricant, with the addition of a little sulphur or soapstone powder, will sometimes cure the trouble. For severe cases, slowing down of the engine and cooling by a stream of water will be necessary. Water cooling of a hot bearing is, however, not considered the most desirable remedy, as sudden contraction of the heated shaft or bearing may lead to cracks and flaws; at the same time the water keeps the oil from the bearing surface and obliges the engineer to keep the water on it continually.

If the damage is severe, the engine must be stopped and the brass, if still in useful condition, be fitted with new Babbitt metal, while the shaft must be filed and again be brought to the best possible condition of smoothness and finish. Where the bearing is broken by seizing, a substitute may need to be fitted.

If all bearing brasses, caps and stud bolts of the shafting are

made interchangeable, a great saving in spares can be effected, and breakdowns often very rapidly remedied. Heavy logs of wood are sometimes bolted together for an emergency bearing, with a notch, smoothed and fitted to the shaft, while the regular cap, or another wooden block, is fitted on top. Particularly in the shaft alley, such makeshifts, thoroughly secured, may do good service in the support of the shafting.

The thrust bearing is the most intricate and delicate of all the bearings, requiring the best attention to avoid serious trouble. If the box itself is fractured or injured, patching will probably be the most efficient remedy.

Often additional body-bound, holding-down bolts may distribute the strain more effectively than before and ease the bearing. If the horseshoes are warped or broken, spare ones or substitutes must be fitted.

Particularly in a rough sea, with occasional racing of the propeller, the full-bearing surface proves none too large, and broken horseshoes should be replaced as soon as conditions permit.

Flat iron bars, notched at the ends to fit over the longitudinal bolts between the nuts, and bent over and across the shaft, have also been used to advantage. Riveted to each bar are two pieces of plate, of the shape of the bearing surface. These are punched full of holes, and carry a thick, protruding plug of Babbitt metal in each hole.

By filing, these plugs are reduced to an even surface on each side, and at such distance from each other as to fit exactly between the collars of the thrust shaft.

736. What breakdowns may occur in the stern tube?

Breakdowns in the stern tube occur generally from the grounding of the after part of the ship, through striking floating objects by the propeller, or by fractures of the propeller

shaft, or the propeller itself. In each case, little can be done in the line of repair, but all effort must be directed to the work of preventing large masses of water from entering the after-hold or the shaft-alley of the ship.

When the propeller and the after end of the shaft have lost support in the stern post altogether, it will prove a difficult task to keep the stuffing-box on the bulkhead. It has proved, in such cases, advantageous to push the shaft as far aft as possible, until the propeller is jammed tight against the wreckage of the rudder or post, and to prevent the end of the shaft from swinging about under the movements of the ship by fitting heavy shores against it, thus avoiding further destruction of the bulkhead.

The bulkhead in the shaft-alley and around it should be stiffened, shored and braced in the most substantial manner that the condition will permit. The entire safety of the ship may depend upon the rigidity and strength of this bulkhead.

737. What breakdowns may occur in the condenser?

The breakdowns to which the cast-iron condenser shells are most exposed are cracks, due to unequal expansion, which, in most cases, may be patched by an application of cement, or be so fitted with a caulking strip of copper on the outside that the external atmospheric pressure will tighten the joint. Very obstinate air leaks may occur when the cracks are in an end flange, making them extend around the corner.

Patching and caulking with metal or cement may both have to be resorted to, as required by the case. The tubes, if split, can be best replaced by spare ones, or if these are not on hand, the old ones may be soldered.

The water chest and circulating water pipes are generally not troublesome, as they are easily repaired by patching.

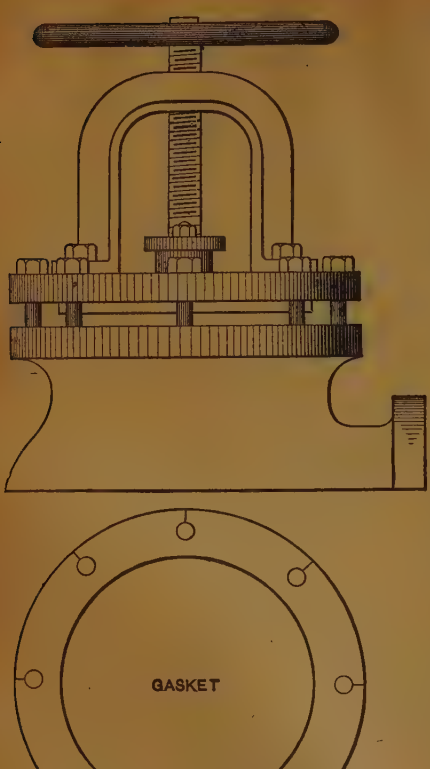


FIG. 204.—Diagrams, Showing Method of Replacing the Gasket on an Injection Valve, while the Vessel is in the Water. On account of leaks it was necessary to set in a new gasket, which operation was accomplished, briefly, by "slacking back" on the nuts and screwing down hard on the hand-wheel alternately. The effect was to produce sufficient slack to enable the cutting out of the old gasket. The new gasket was then slit as shown, and cuts made to the edge from each bolt hole so that it could be readily worked on, without further overhauling the valve.

738. What breakdowns are liable to occur with the stationary parts of the pumps, auxiliaries, valves and piping?

The breakdowns on cylinders, framing, bed-plates, etc., of pumps and auxiliaries are very similar to those in the main engine, and may be repaired in a similar manner, by patching. Valves can be replaced by spare ones, or by exchanging with one in a less important place.

Sea valves may be troublesome by the leakage of water into the bilge. Where the sea valve is attached, with through bolts, to a neck reaching out from the side of the ship beyond the framing, it is sometimes possible to blanket the opening in the neck by a piece of sheet metal. This piece of metal is cut in circular form to fit loosely inside of the bolts, covering the opening with a good lap.

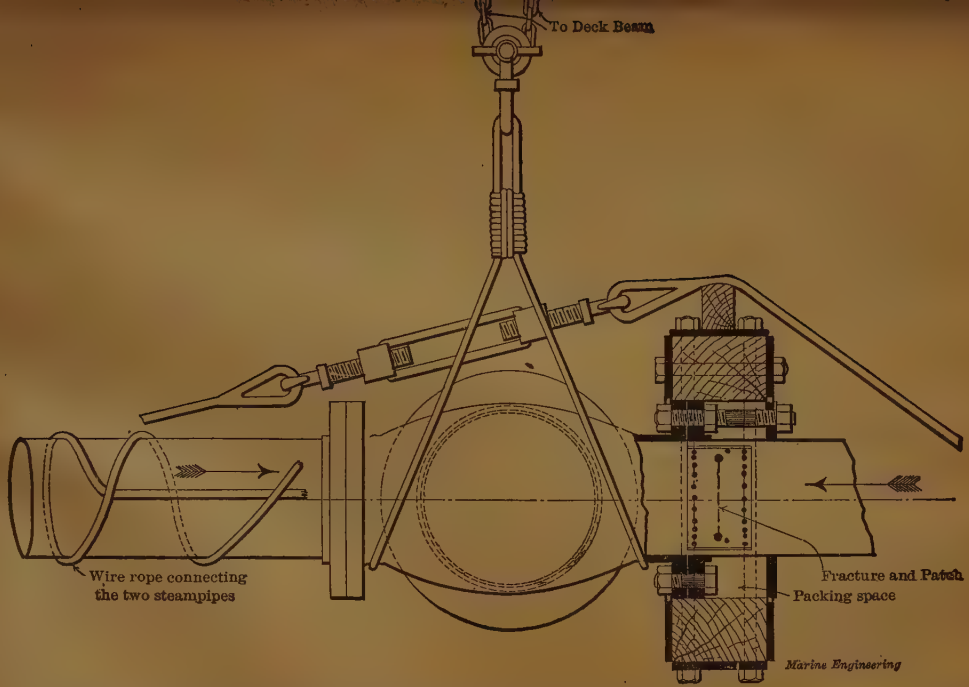
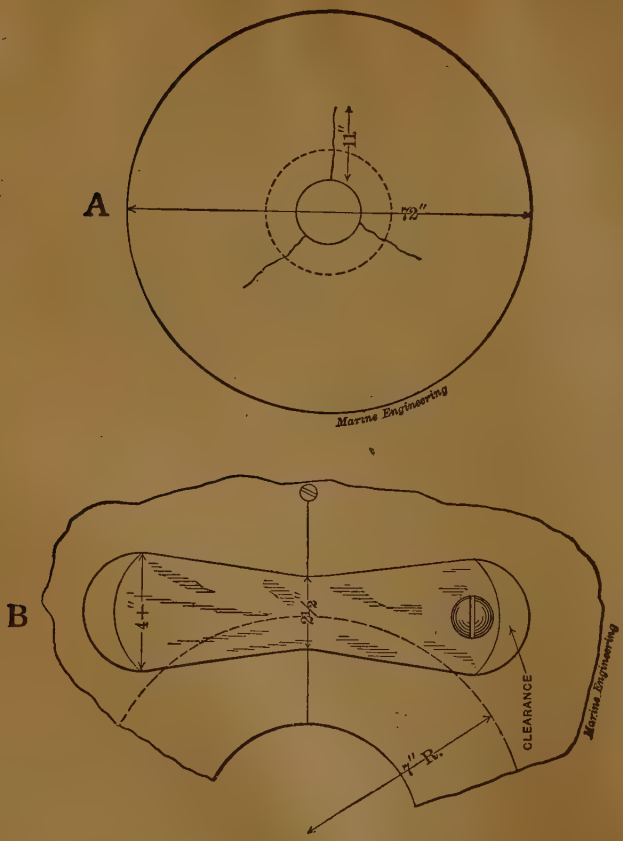
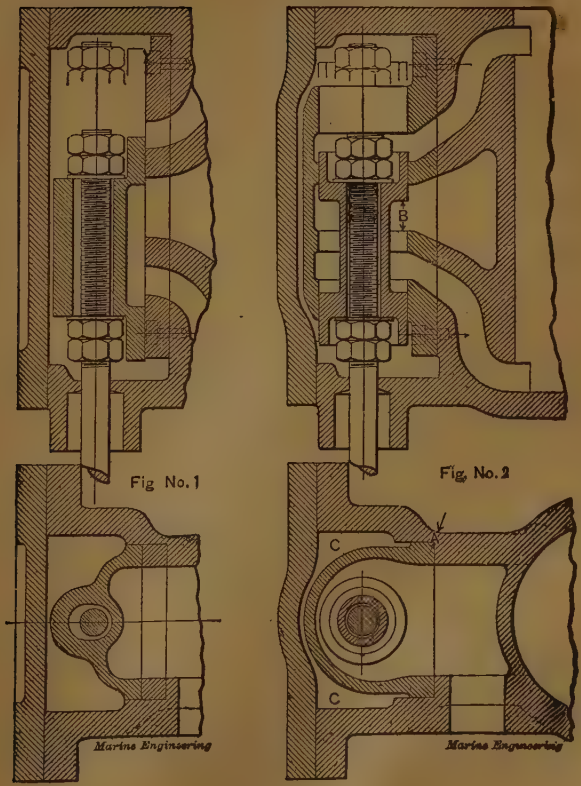


FIG. 205.—Diagram Showing Repairs on a Fractured Main Steam Pipe. The crack or fracture was first patched. A packing space was then formed around the fracture by bolting two halves of a wooden stuffing-box, as shown, the packing consisting of pieces of old circulating pump valves, etc. This expedient having failed, a new packing was arranged on similar lines, and the repair further strengthened by supporting the weight of the pipes from a convenient deck beam, and connecting the two pipes drawn together with wire rope connected by a turnbuckle.



FIGS. 206, 207.—Diagrams Showing Method of Repairing Cracks in a Low-pressure Piston. A template was made and three steel patches shaped to it, as shown at B. The template, heated red hot, was laid on a piece of ⅛-inch sheet steel, scribed all around, while hot, and another template worked out on the scribe lines. The piston was then drilled and chipped across the cracks to this last template, and the patches heated and put in place. They were afterward checked with screws, as shown.



FIGS, 208, 209.—Diagrams Showing Method of Making a Piston Valve from a Defective Slide Valve on the Cylinder of an Independent Auxiliary Engine. By removing the false face of the slide valve, room was gained for a piston valve chamber. Limited room in vertical direction obliged the nuts to be recessed into the piston valve body.

When cutting this piece, two strips of metal are left diametrically opposite that reach out between two bolts and serve as handles for directing it into place.

The through bolts on one side of the connecting flanges are all removed, and those on the other side loosened sufficiently to allow the sheet to be slipped under the valve.

It should be handled rapidly, to reduce the heavy leakage through the loosened joint, as much as possible. After adjustment, all bolts are replaced and drawn up tight, and the sea valve may then be opened and repaired to best advantage.

739. What breakdowns are likely to occur with the pistons and valves?

The pistons and valves are liable to develop cracks or fractures that allow the steam to pass from one side to the other, or prevent their rigid attachment to the piston rod or valve stem. Repairs by raised or sunken patches will prove a help for most cases.

Precaution must be taken, however, that the raised patches do not strike any part of the heads or covers. It may be necessary to raise the top head by extra heavy packing, or to fit a distance ring, packed on both faces to obtain the necessary clearance between the patches and the head. Patches on the under side of the piston are the most troublesome to apply and to provide clearance for. It may also be necessary to put liners under the connecting rod brasses or otherwise to raise the piston sufficiently to give clearance for the patches. It is evident that the upper side must also be raised. With the valves the clearance is likely to prove less troublesome.

The greatest difficulty, particularly in slide valves with intricate passages, is to close the cracks in the dividing walls sufficiently to prevent steam from leaking through.

With serious fractures, which would be hopeless as regards repair, the cutting-out of the particular cylinder will probably be

the only possibility. The connecting rod and eccentric rods will have to be swung out of the way of the shaft, the valve removed and the rest of the moving parts securely blocked. The valve chest and cylinder will thus become part of the receiver space, reducing the expansion one step. It will be advisable to reduce the pressure and power correspondingly.

740. What breakdowns are likely to occur in the piston rod and valve stem?

The piston rod and valve stems are subject to very annoying breakdowns, which are, in most cases, not easily repaired. This is due to the fact that they must retain their smooth cylindrical form for passing through the stuffing-boxes or fitting into valves, pistons or cross-heads.

The defects generally appear as transverse or diagonal flaws, cracks or breaks, which are sometimes due to imperfections in the material or workmanship, and sometimes to overload or local strains. Cross keys often prove effective, or two or three sunken longitudinal keys tapped to the rod above and below the fracture by countersunk screws.

It is apparent that everything must be filed and smoothed to the same cylindrical surface. Generally, the section of the rod is sufficiently large to permit such a reduction of the effective area, without proving dangerous, and also allows the repaired rod to be used, at least, with reduced pressure and speed.

Frequently the fractures are located near one end of the rod, in which case a hole may be drilled on the longitudinal axis into the solid part, and the two be connected by a central tap bolt, large enough to carry the tension strain.

741. What breakdowns are likely to occur in the cross-heads and the connecting rod?

The flaws and cracks that may be caused, for one reason or

another, on the cross-head, or connecting rod, are comparatively easy to repair by patching, as the parts are fairly accessible. Smaller parts, like bolts and slipper plates, may usually be replaced by spare parts, or substitutes built by the engineer force.

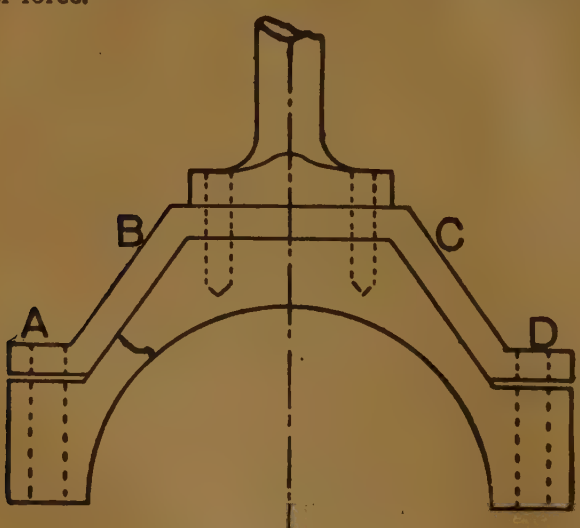


FIG. 210.—Diagram Showing a Ready Method of Repairing a Broken Eccentric Strap. This cut shows the upper half of an eccentric strap fractured completely through, as indicated between A and B. The repair was effected by bending a flat bar of iron, A B C D, so as to fit the strap, leaving small clearances below A and D, so as to permit the end to be drawn down tight by bolts. Two holes were then drilled for the strap bolts and two others for the eccentric rod studs. Thus repaired, the eccentric was in shape to work nearly as well as before the mishap. As may be understood, however, the repair would have the effect of lengthening the eccentric rods by the thickness of the iron strap, A B C D, which necessitated a corresponding shortening of the valve stem, thus leaving the valve in the same relative position without change in its operation. The eccentric gear, thus repaired, operated very well, and at nearly full speed, through the 1,400 miles to port, where permanent repairs were effected.

In direct-connected air, feed or bilge pumps, the rocking levers, or the connecting links, may give out. Patching the beams, or replacing them with substitutes cut from pieces of plate, with doubling pieces under the pins or the rock-shaft connections, will often prove the best method of repair.

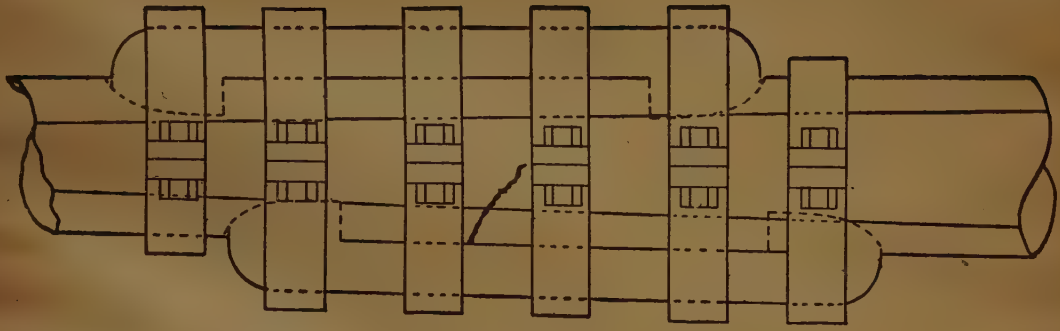


FIG. 211.—Diagram Showing Method of Making an Emergency Repair on a Cracked Connecting Rod. A crack, originating in a flaw of the metal of the steel rod, had worked nearly half way through the diameter, as shown in the cut. The method of repair adopted was to drill and chip two notches in the rod, two on either side, as shown. Two large steel bars were then formed by the blacksmith to fit into these notches, and were secured in place by six straps, binding the steel bars to the rod.

The pump links, if giving out in the connecting rods, can be conveniently replaced by plain bolts and distance pieces between the end bearings. The pins and connecting rods may often be strengthened by large central bolts and longitudinal sunken keys.

The brasses, caps and bolts, in most cases, may be replaced

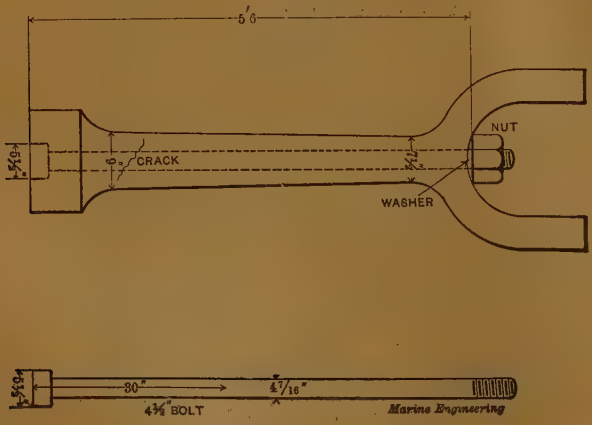


FIG. 212.—Diagram Illustrating Another Emergency Repair on a Cracked Connecting Rod. Since this connecting rod had a hole extending through its entire length as indicated by the dotted lines, the repair was as follows: The rod was taken down, placed on the lathe, and the hole countersunk at the stub end to a depth of two inches. A spare boat davit was then cut to proper length for making a bolt to extend entirely through the hole in the connecting rod; one end of it being upset to form a head, which was turned to the exact size of the countersink, the other end being threaded to receive a nut, as shown. The rod was then heated uniformly over a charcoal fire, so as not to twist it; the long bolt was driven into the hole through the rod; the nut set up against its washer, and the rod allowed to cool. After this, a small hole was drilled at each end of the crack, to prevent it from spreading. The repair, thus completed, served to retain the connecting rod in good condition during a voyage of 10,000 miles.

by spares, or otherwise forged pieces, if they have a sufficient number of holes for babbit plugs, may efficiently replace the broken pieces, with the aid of washers and liners.

Keys, gibs, and straps are easily replaced with the usual appliances on hand.

742. What breakdowns are likely to occur in the valve driving gear?

The valve driving gear, consisting of eccentrics, rods, links and reversing gear, admits of easy repair, as most of the parts are comparatively light, and of sizes readily shaped from the stock on hand. The loss of time proves, in this case, the most annoying feature of the accident.

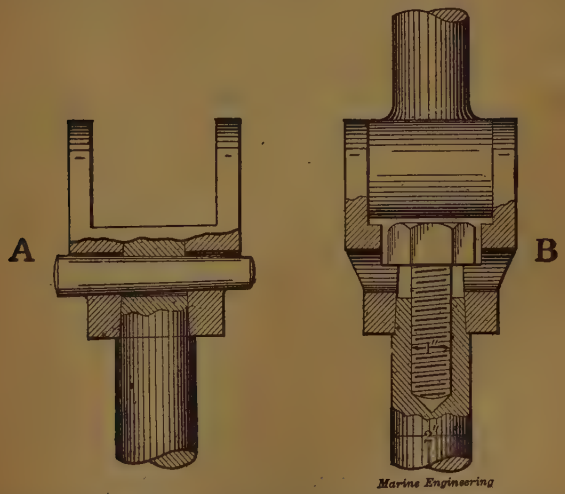


FIG. 343.—**Illustration of an Emergency Method of Repairing a Broken Piston Rod on a Reversing Engine. The rod parted in the keyway, making it necessary to adopt some other method of connecting the cross-head on. The rod and cross-head were drilled and counterbored for a tap-bolt under the eye of the connecting rod. The original condition of the rod is shown at A; the repair, at B.**

The most frequent defects develop in the eccentrics and straps, which often break clear through. If room permits, patches on the side of the eccentric may strengthen it sufficiently to allow it to do its work. Where the break is at the key, or where the space is too cramped, the backing eccentric, if of the same size as the forward one, may be put in its place. The backing rod must in this case be removed, and its end of

the link be securely strapped from above and below, so that it can move neither up nor down. The link is thus converted into a lever, having its fulcrum at the strapped end, being guided and held horizontally by the drag rods, and swung up and down at the ahead end by the forward eccentric rods.

It is evident that backing would thus be rendered impossible, and that, on the approach of crowded harbors or docks, tugs would be required to handle the ship entirely.

Breaks in the strap have been repaired by fitting, above or below the broken one, additional bar iron straps, which transmit the strains to the clamping bolts.

It may prove advantageous to place the broken and repaired strap on the backing eccentric and the sound strap on the ahead eccentric.

The eccentric rods may be repaired in the same manner as connecting rods.

In small sizes the rods are sometimes connected to the straps by screw threads and nuts, that may strip or become too loose for a full load. Keys may be fitted sometimes in their place, as circumstances permit. Link pins or blocks can be replaced by spare ones or substitutes. The reversing gear, being used very infrequently, seldom gives occasion for repairs.

With reciprocating, reversing steam cylinders, the piston may overrun, if the hand floating lever is out of order, knocking out its head or inflicting damage to other parts of the gear or links.

Minor accidents, such as the loss of rock arm keys, breaking of the shaft bearing and the like, may appear, but are repaired without difficulty.

743. What breakdowns may occur with the crank shaft?

The crank shaft, under its many severe bending and torsional strains, is exposed to numerous possibilities in the way

of accident. The flaws or fractures may occur in crank pins, webs, shafts or couplings.

The crank pins are liable to be fractured near the web, particularly those forged together with the web. If the pins are hollow or so situated that central holes can be bored through them, heavy bolts with nuts or upset ends make a very effective repair.

The webs are more likely to show flaws near the pin or

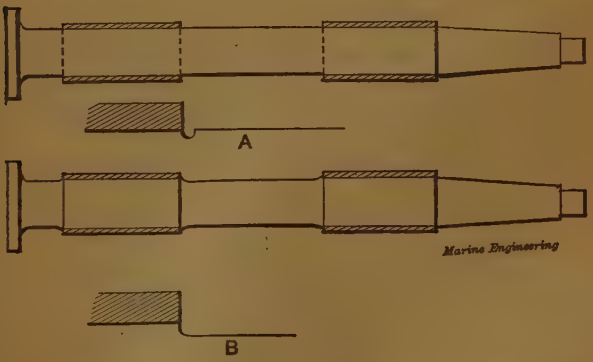


FIG. 214.—Two Forms of Fitting Brass Sleeves on Propeller Shafts. The groove in A may lead more easily to fracture than B.

shaft. Straps around the fractured part, set up tight by bolts or keys, may enable the shaft to transmit, at least, part of the normal power. Breaks in the shaft, particularly in the bearings, may be troublesome cases to deal with.

With hollow shafts, a solid central pin or bolt, supplemented by longitudinal sunken keys, may repair the shaft for partial duty. The couplings are liable to give trouble by shearing the bolts, sometimes breaking that part of the coupling outside of the bolt. New bolt holes and bolts may be fitted, and cross

keys, sunken into each face, greatly add to the strength of th connection, by relieving the bolts of a large part of the tor sional strain.

Where the shaft is fitted in interchangeable sections th injured part is best placed under the forward cylinder, wher the least power is to be transmitted.

If beyond repair, the corresponding cylinder must be cut out as already described.

The maximum pressure upon the crank may be somewha

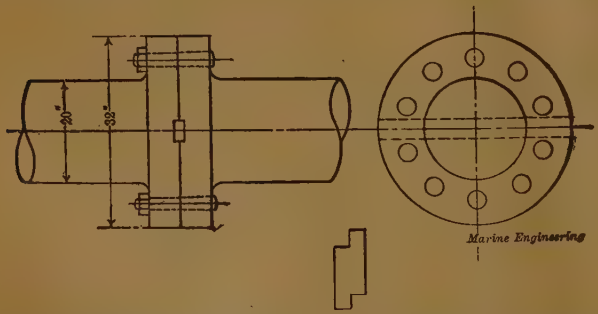


FIG. 215.—Diagram Illustrating Disablement to the Coupling of a Main-engine Crank shaft. The coupling flanges were connected by ten bolts, as shown, but on accoun of some unforeseen accident, all of them were broken off short between the flange the working of the engine resulting in bending the key, which alone held the flang faces from slipping, into the section shown at the base of cut. Repair was effecte by drilling out and replacing the bolts.

decreased by lengthening the period of admission and decrea ing the expansion.

This will keep the back pressure high, and thus reduce th mean effective pressure upon the piston, throwing more wor upon the other cylinders.

This repair is advisable also where fractures in pistons, pisto rods, rods, cross-heads or connecting rods render it desirabl to relieve the injured parts somewhat from their normal loa and strain.

The changing of the steam distribution may be effected b

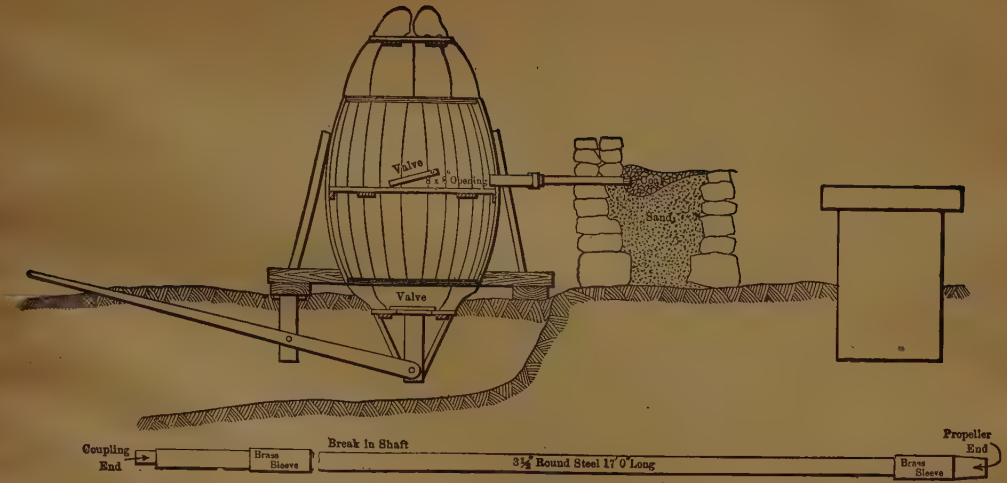


FIG. 216.—Diagram of an Improvised Forge on the Shore of a West Indian Island, used to weld a broken propeller shaft. In this emergency it was necessary to improvise some kind of a forge, which was done with the help of an old deck cask as a bellows. The two ends of the shaft, broken apart as shown in the cut, were welded by inserting a piece of scrap iron which was welded to the short end of the shaft by a V-shaped weld, and then welding on the long end of the shaft. The shaft was straightened by use of two V blocks fastened to a lower mast of a wrecked vessel, being inserted in them while hot. When completed the shaft was about ⅛ inch shorter than originally, but the job was so well done that no further repairs were needed at the end of five years.

cutting down the steam lap, and by reducing the angular advance of the eccentric. The steam lap can be cut down effectively by drilling a row of holes close together along the steam edge of a slide valve or a plug piston valve. With packed piston valves and follower rings, notches may be cut into the rim, or ring, that will allow the steam to enter the cylinder during a longer period. To shift the eccentric, new key ways must be cut, and the eccentric secured in such a position that the lead remains of the former dimension.

With single or compound engines, such a change, coupled with a reduction of the admission pressure, may prove of considerable value. For triple or quadruple expansion engines, it may prove more advantageous to save the time and cut the injured cylinder altogether out of the working cycle.

744. What breakdowns are liable to occur in the shafting and the propeller?

The breakdowns in these places generally consist in transverse or diagonal flaws, or fractures, splitting of couplings and shearing of bolts. Where the injured part is accessible, patches and longitudinal and cross keys, held by clamps, prove the most effective remedy.

All interstices are run solidly, full with Babbitt metal, to prevent any shifting, loosening, or slipping-out of the keys or clamps. Couplings and bolts are treated like those of the crankshaft. The thrust shaft, if broken within the range of the collars, may require special forged patches, for the fitting of which some of the collars may need to be cut away.

The power of the engine may have to be reduced to suit a decrease of thrust-bearing surface. It will then be advisable to provide temporary bearings of wood, or to hang the shafts in chains, as near to the fracture as they can be fitted to prevent any extra bending strains upon the injured piece.

A nearly hopeless case is the fracture of the propeller shaft in the stern tube.

If far enough forward to be within reach from the after peak, the stern tube can be cut away and the shaft repaired in the same manner as other parts of the shafting. If the break is in the after-bearing, or at the propeller, it is probable that

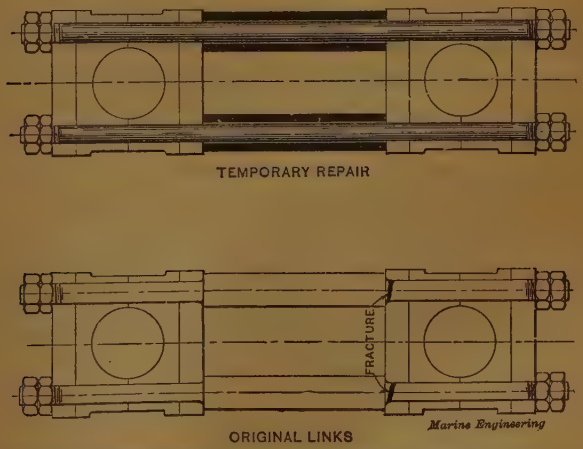


FIG. 217.—Diagrams Illustrating a Repair on Fractured Pump Links. With the engine in question, the air, feed, bilge and circulating pumps were all worked from the cross-head of the low-pressure cylinder. Great trouble was experienced from the fact that the nuts on the forward pumps would constantly slack back. Finally, the bolts fractured at the shoulder, as indicated. The repair was made by threading two steel rods of the proper length and diameter, and inserting them, as shown, with two lengths of iron pipe as distance pieces.

the broken end will drop out before any remedy can be applied.

The propeller hub may become split or work loose on the cone by the loss of the securing nut or key. Frequently these accidents occur in heavy weather and in conditions where nothing can be done other than to try clamping the shaft and waiting for moderate weather, to discover if repairs can be effected. There are cases on record in which a ship, in light

condition, has been trimmed by the head through water ballast to such an extent that the hub of the defective propeller was within reach of the working force of the engineers, so as to be successfully replaced with a spare one during favorable weather. It is also possible sometimes to thus replace broken blades, if they are bolted to the hub.

Fractures in the shafting, and loss of the propeller, prove serious dangers, not only by depriving the ship of its propulsive power, but also by occasioning a running-away and complete destruction of the engine itself, on account of entire removal of load, with increased rotative speed. The suddenness of such occurrences requires the permanent attention of the engineer on watch, and renders it desirable that the throttle valve should virtually never be out of the reach of his hand.

In heavy weather, under severe pitching, with such movements of the vessel as at one time lift the propeller high out of the water, while at other times burying it deeply, continuous alternate closing and opening of the throttle valve are required to prevent racing, in one case, or stopping, in the other.

745. What breakdowns are liable to occur in the air pump?

The breakdown of the air pump may take place in any one of the three valve systems; in the plunger or piston; in the steam cylinder gear of independent pumps or the transmitting gear in the connected pumps. The valves can generally be patched or replaced, as the most common defects consist in wearing away and breaking of the valves, studs or guards. The plunger or piston may crack around the centre hole, or at the packing rings. If the crack is slight, patching may prove sufficient, but, with large fractures, this mode of repair may render difficult the maintenance of a vacuum.

The driving mechanism will require about the same repairs as before mentioned for the main engine.

If the air pump is beyond repair, substitutes must be employed, or the vacuum will have to be dispensed with. For substitutes a reciprocating circulating pump, the feed pump or the donkey, fire or bilge pump may be employed, according to availability. If the feed pump is provided with a suction from the air-pump channel, it may be able to remove the water, but not enough air to furnish a satisfactory vacuum.

It is sometimes possible to establish one or more extra connections at hand, or manhole covers, that allow the donkey, bilge pump or fire pump to concentrate its suction capacity also upon the production of vacuum, although less effectively than with the air pump.

When no vacuum can by any means be obtained probably the best thing to be done is to maintain as much condensation as possible, remove the water with a pump from the bottom of the condenser, and allow the steam or surplus water to find its way overboard through the air pump after the valves and piston have been removed through the hot well and delivery pipe.

746. What breakdowns are likely to occur in the circulating pump?

The common breakdowns of the circulating pump are in the valves and bucket of the reciprocating pump, or in the runner and steam gear of an independent rotary pump. For minor defects repairs can be made by patching, or substitutes, in a manner similar to that described in connection with the air pump and parts of the main engine. If the air pump is large enough, jet condensation may be resorted to, either by using a special injection cock or valve, or by removing a number of the upper tubes. This, however, will introduce large quan-

tities of salt into the boiler, with the consequent danger of rapid scale accumulation.

It is generally preferable to employ a substitute for the circulating pump, if such can conveniently be connected to the condenser. Fire pumps, donkey or bilge pumps have been used successfully, making pipe, or even hose, connections at the hand-holes of the condenser water chests. Large ballast pumps

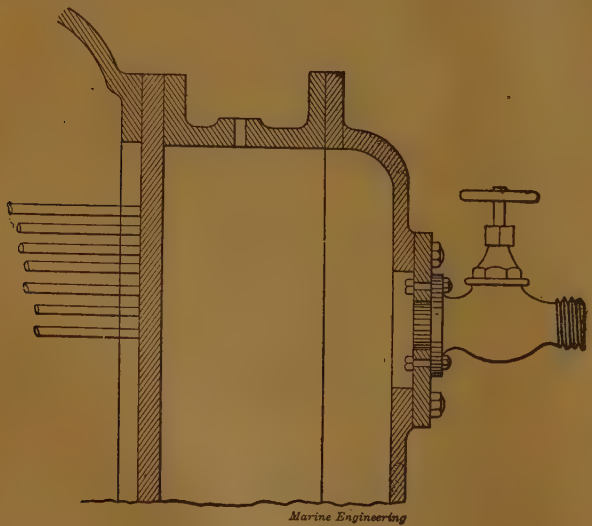


FIG. 218.—Diagram Illustrating a Method of Connecting the Fire Pump to the Condenser, owing to the breakdown of the circulating pump. Two of the hand-hole covers on the bonnet of the condenser were removed, and a 2½-inch hole cut in the centre of each. Bolt holes were then drilled around each of these holes, so that a flange hose-valve could be bolted in place on them. Hose connections were then made to the fire pump, which was used to circulate water in the condenser.

often have a pumping capacity capable of amply supplying the needed condensing water.

747. What breakdowns are liable to occur with feed pump, donkey, fire or bilge and ballast pumps?

Breakdowns in the reciprocating pumps generally occur in

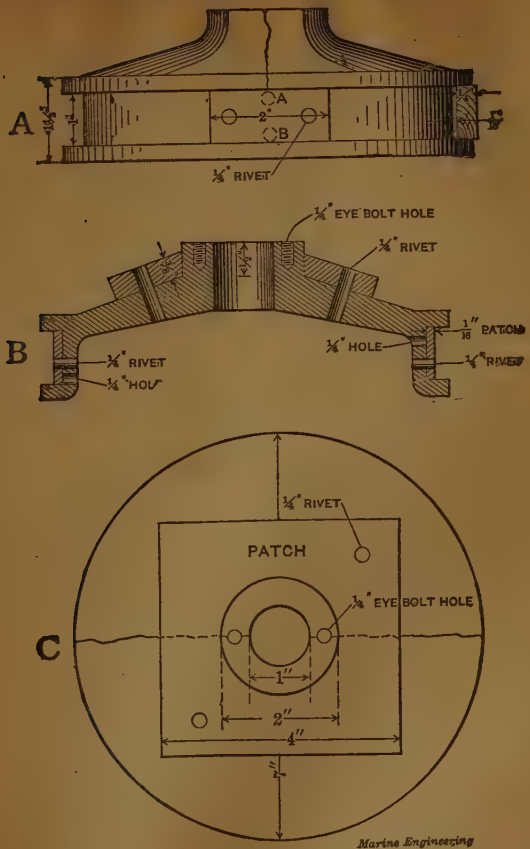


FIG. 219.—Diagrams Illustrating Repair to the Piston of a Dynamo Engine. The piston was cracked across its diameter and down either side, as shown at A and C. To repair the damage, one-quarter inch holes were drilled at the ends of the crack, as shown in B and C, and patches were fitted. The top patch was a washer, 4 inches square by 3/8 inch thick, of sheet steel, with a hole in the centre of 1½ inch diameter. This washer was heated and dished, the cylinder head being used for a former. Rivet holes in these patches were spaced to draw. The top patch was then heated, hung on the parallel part of the boss and squeezed over in the vise. In cooling, the crack, where it had already extended to the lower flange, as at A, went through, but when the piston was tried on the rod it did not open a particle. The engine was operated perfectly with this repair.

the steam or water valves, or pistons. The valves may giv out, stick or leak, or the studs and guards, supporting an guiding the valves, may become deranged.

The pistons very frequently give out in the packing, thu allowing large leakage, or they may become cracked o broken. Repairs have been made, in cases where spares wer not on hand, by building up pistons with plate discs, usin pieces of pipe as distance pieces, and connecting tap bolt which, carefully packed, did good temporary service.

748. What breakdowns are likely to occur with the elec trical machinery?

The electrical plant may break down in the driving powe or the electrical equipment.

The engine and its parts may be repaired in manner simila to that employed in the parts of the main engine.

The electrical equipment may prove defective in th dynamo, the wiring, or the lamps or motors. For the dynam sometimes a spare armature is provided, which may be subst tuted for the old one.

Burning-out of the fields will probably require shuttin down of the electrical service and resorting to oil or othe lighting.

The wiring may conveniently be repaired, after detectin the defects, with the help of a battery, a bell or galvan meter.

Broken lamps can be replaced by spares, while defectiv motors generally require the suspension of the special servic

749. What breakdowns are liable to occur with fa engines, refrigerators and steering gear?

The breakdowns of these engines require practically the sam kind of repairs as the other rotating or reciprocating aux iaries, in pistons, valves, shafts, eccentrics and rods, etc.

750. What influence has interchangeability of parts upon convenience and rapidity in executing repairs?

The greatest interchangeability is highly desirable, as then one spare will readily fit in a number of places, or apart from an unimportant position can be substituted for a broken part in a more important position.

Interchangeability may extend in multiple-cylinder engines to all piston rods, cross-heads, connecting rods, sections of crank shaft, thrust-bearing horseshoes, valve stems, links complete with drag rods, eccentric rods and eccentrics. The auxiliaries may partake, profitably, of this feature by making parts of blower, circulating and dynamo engines alike, also by giving to all pumps piston rods, pistons and valves of the same size, as much as possible, even using the same size pump for feed pump, donkey, fire pump and bilge pump. Stuffing-boxes may often be interchangeable for piston rods and valve stems on the main engine and, in other sizes, for the auxiliaries.

Valves and piping can often be quite conveniently constructed in only a limited number of sizes that may thus be replaced from a small stock of spare pieces. Uniformity of size in flange connections and bolts proves of the greatest benefit in remedying certain suddenly-appearing defects.

751. What tools prove the most useful in making repairs?

The most useful tools for making repairs are those for drilling, boring, tapping, chipping, slotting and facing, in either portable or stationary form, besides the appliances for heating and forging, soldering and brazing.

The machine shop on board large ocean-going ships may profitably contain a good-sized radial drill press, a lathe, large enough to take connecting rods, piston rods and valve gear parts and fitted with a face plate on the other end of the head

stock, in order to permit of swinging such objects as pistons or cylinder heads in front of a special tool rest.

A very convenient tool is also a small slotting machine. Of course, all hand tools and smaller appliances, as well as pulling and lifting jacks, are provided in sufficient numbers and variety of sizes.

Nearly all repairs will require drilling or boring, either on portable pieces or patches that can be taken to the drill press or lathe, or on the stationary parts of the engine. In the latter case portable tools are required. Frequently hand ratchets only are available, thus rendering heavy repairing a slow and fatiguing task, besides leaving the ship, in heavy weather, for a long time at the mercy of the waves.

Where electric lighting is employed on shipboard, a lead could be fitted through boiler room, engine room and shaft-alley in water-tight insulation and with a number of outlets for attachment of cables leading to small motors. These motors could transfer their power by flexible shafting to portable drills, gaining thereby a great saving of time and output of work; also allowing, through the great flexibility of the system, access to almost all parts of the machinery.

Drilling, most frequently, must be supplemented by chipping for the fitting of longitudinal or transverse keys, patches, etc. Power application to the operation of chipping, caulking, cutting and driving rivets, expanding and beading tubes can be obtained at comparatively small cost by the installation of an air compressor in the engine room, which, with a short lead of pipe and long flexible hose connections, can supply power for several of the highly-effective pneumatic tools, used in all ship yards and boiler shops for the same kind of work.

The great advantage of such power application lies in the saving of time that may prove of the utmost value for the safety of the ship.

The engineer's force of an ocean-going ship is of necessity limited. However, with power tools at command this small staff can execute large repairs effectively and successfully.

RULE II, 20—*Fusible Plugs.*

Manufacturers of fusible plugs shall furnish the Supervising Inspector General a sample plug from each heat for examination and test, but where more than 250 plugs are poured from the same heat, a sample plug shall be furnished for each 250 plugs or fraction thereof. The samples furnished shall bear the same number for any one heat and shall represent the heat from which the sample is poured.

In transmitting samples of fusible plugs to the Supervising Inspector General, the fusible plugs and the letters of transmittal shall be addressed as follows: "Supervising Inspector General, Steamboat-Inspection Service, Department of Commerce, Washington, D. C."

One letter of transmittal shall be required for each heat.

In letter of transmittal the following information shall be stated:

Number of heat.

Number of fusible plugs manufactured from the heat.

Number of samples of fusible plugs from the heat transmitted.

Name of manufacturer or initials stamped on casing of plug.

Manufacturers of fusible plugs shall stamp on the larger end or face of the casing their name or initials for identification and shall file with the Supervising Inspector General of the Steamboat-Inspection Service at Washington, D. C., a certificate duly sworn to that such plugs are filled with tin of the character required by this rule and made in accordance therewith.

Following is a general form of affidavit to be followed by manufacturers of fusible plugs

State of———, County of———.

I hereby certify, on this ——— day of ———, 191—, that I am ——— ———, of the
(State owner or name position.)

manufactory of ———, at ———, in the State of ———; that all fusible plugs furnished for use in boilers of steam vessels under the jurisdiction of the Steamboat-Inspection Service by the said manufactory will be filled with tin of the character required, and will be made in accordance with the rules and regulations of the Board of Supervising Inspectors, Steamboat-Inspection Service, governing the manufacture of fusible plugs; and that I am authorized to make this certificate.

———————.
(Signature of manufacturer.)

Subscribed and ——— to before me this ——— day of ———, 191—.
(Sworn or affirmed.)

(Signature)———————,
Notary Public.

[NOTARY'S SEAL.]

The certificate shall be executed by some person having authority to make the statements contained therein.

On receipt of a properly executed affidavit by the Supervising Inspector General, the inspectors of the Steamboat-Inspection Service and the merchant marine generally shall be notified. (Secs. 4405, 4418, R. S.)

Engineers have often shown great ingenuity in such powe application to the work of repairs. The winches, with thei independent steam cylinders, have been used to drive, by gea or belt connection, improvised lathes in which it has bee possible to repair some of the heaviest parts of the machinery

PART NINE.

MATERIALS AND STRENGTH.

CHAPTER TWENTY-SEVEN—CONSTRUCTIVE MATERIALS AND TESTS OF STRENGTH.

Properties of Materials

The following table gives the general range of values to be expected in various materials when subjected to various kinds of loading.

Material	Specific gravity	Ultimate strength, lb. per sq. in.	Elastic limit, lb. per sq. in.	Yield point, lb. per sq. in.	Ultimate elongation, per cent.	Modulus of elasticity, 1000 lb. per sq. in.
Cast iron	7.207					
Gray iron		15,000–18,000	5,000–6,000		0.1–1.0 in 2 in.	12,000 14,000
Better grade		20,000–30,000	10,000–24,000			
Malleable cast iron		25,000–48,000	12,000–22,000	12,500–19,000	1.0–3.0 in 2 in.	
Wrought iron	7.78	42,000–52,000	21,000–26,000	28,000–34,000	22.0–30.0 in 8 in.	26,000 29,000
Steel						
Extra soft		45,000–55,000	22,500–27,500	30,000–33,000	27.0–33.0 in 8 in.	
Soft (C.–0.08–0.15)	7.833	50,000–60,000	25,000–30,000		25.0–30.0 in 8 in.	
Medium (C.–0.15–0.30)		60,000–70,000	30,000–35,000	37,000–44,000	22.0–25.0 in 8 in.	
Hard (C.–0.30 up)		70,000–80,000	35,000–40,000	38,000–45,000	18.0–22.0 in 8 in.	
Rail (C.–0.55–0.75)		101,000–115,000	50,000–57,000	50,000–57,000	12.0–15.0 in 2 in.	
Ingot iron (C.–0.01–0.15)		42,000–60,000			18.0–36.0 in 8 in.	
Steel castings	7.917					
Soft		60,000–72,000	30,000–35,000	40,000–46,000	22.0–up in 2 in.	
Medium		72,000–78,000	36,000–39,000		16.0–22.0 in 2 in.	
Hard		78,000 up	39,000 up		12.0–16.0 in 2 in.	
Steel forgings		75,000–90,000	37,000–45,000		22.0–24.0 in 2 in.	
Spring steel						
Untempered		101,000–135,000	50,000–67,000		3.0–6.5 in 8 in.	
Tempered		130,000–200,000	110,000–170,000		0.5–2.1 in 8 in.	
Nickel steel						
Structural (3.5 per cent. N)		100,000–120,000	50,000–60,000	58,000–70,000	16.0–20.0 in 8 in.	
Forging (annealed)		80,000	40,000		30.0 in 2 in.	
Forging (oil-tempered)		98,000	75,000		25.0 in 2 in.	
Vanadium steel						
Annealed		54,000–96,000	27,000–48,000		22.0–24.0 in 2 in.	
Oil-tempered		125,000–232,000	100,000–180,000		11.0–21.0 in 2 in.	

Modulus of elasticity of all steels varies from 28,000,000 to 31,000,000; average, 30,000,000.

* Other Strength Functions. Compressive strength of cast iron = 6 × T. S. (Tensile Strength). Compressive strength of wrought iron and steel to be taken as the yield point. Shearing strength of cast iron = 1.10 × T. S.; of wrought iron = 0.85 × T. S.; of hard and soft steels = 0.75 × T. S. Bending strength of modulus of rupture of cast iron = 2 × T. S.; of wrought iron = T. S.; of steel, to be taken as the yield point. Coefficient of expansion for change of 1 deg. Fahr. is .0000065 for steel; and .0000062 for cast iron.

CHAPTER TWENTY-SEVEN.

CONSTRUCTIVE MATERIALS AND TESTS OF STRENGTH

752. What forms of substance are of importance in the construction and operation of marine machinery?

The substances that are of importance in construction and operation of marine machinery are of the gaseous, liquid and solid form. The gaseous substances, generally used as working fluids, are air, furnace gases, steam, ammonia, etc.; the liquid substances, used as working, lubricating or indicating fluids, are water, brine, oil, mercury, etc.; the solid substances, used as retaining, tightening, insulating or filling materials, are steel, iron, copper, brass, tin, zinc, lead, rubber, hemp, felt, asbestos, cement, etc.

The labor of the engineer is largely directed to and required for the end of retaining, admitting, excluding or withdrawing the working fluids, or the power developed from them, by the appliances constructed from the solid materials. These latter, therefore, are, according as they realize the varying degrees of perfection in the accomplishment of their tasks, of the highest interest to the engineer.

753. What qualities of the solid materials are important in the accomplishment of their tasks?

The qualities of the solid materials, important for efficient performance in the construction and operation of marine machinery, may be distinguished as:

(1.) Chemical qualities.

(2.) Mechanical qualities.

754. What are the important chemical qualities of the solid materials?

The important chemical qualities of the solid materials are those that resist corrosion from contact with acid or alkaline working fluids, or from galvanic action, by immersion of different materials in an exciting fluid. The parts easily affected by acid corrosion are the boiler, condenser, pipes, etc., their materials of steel and iron being subject to this influence. Copper and brass, if used in refrigerating machines, would be subject to alkaline corrosion from the ammonia.

Galvanic action is commonly found at numerous points in hull, boiler, engine, piping, etc., attacking most frequently iron and steel.

To secure efficient operation, the materials chosen are either protected from corrosive action by making acid working fluids indifferent or slightly alkaline; by allowing alkaline working fluids to touch only materials immune from corroding influence, or by substituting and sacrificing a special material to the corroding action, and protecting those of greater importance.

755. What are the important mechanical qualities of the materials?

The important mechanical qualities of the materials are:

(1.) Porosity.
(2.) Hardness.
(3.) Strength.
(4.) Toughness.
(5.) Elasticity.

756. What is understood by the term porosity, and where is this quality of importance?

Porosity is a lack of cohesion between the particles of a material, which allows other substances to occupy the inter

stices between the component particles. These interstices are most likely to be filled by gases and liquids. It is evident that this quality of porosity should be possessed as little as possible by the materials and parts employed to retain working fluids at a pressure higher than that of the outside fluid.

Spongy steam cylinders are thus unfit for holding high pressures. For other purposes the quality of porosity may prove highly desirable. In all filters, extended use is made of porosity; the interstices of the filtering material allowing the working fluid to pass through, while the impurities are collected and retained.

Another case where porosity is desirable is found in different lagging materials, like felt, mineral wool, etc. Air is retained in the numerous interstices, acting thus very effectively as a non-conductor of heat.

757. What is understood by hardness and where is it of importance?

Hardness in the quality of the material that renders difficult the separation of each component particle from its neighbor.

Thus, a piece of iron offers great resistance to cutting, or separation of its particles, while a piece of lead is easily divided.

Hardness is also, to some extent, coincident with strength, although the accompanying degree of toughness decides how far it is advisable to make use of this hardness.

The degree of hardness of all materials may be expressed comparatively on a scale such as is used in mineralogy, and in which talcum is graded at unity, while the diamond, the hardest known substance, is graded at 10. In this scale, a material marked 8 can scratch one marked 7, while 7 can scratch 6, and so on. Thus, it will readily be seen, a material high in the scale can be injured by few other materials,

while one low in the scale can be defaced, or divided, by a great many materials. Hardness is, therefore, a valuable quality in the walls of all retaining vessels for making sure that they are well protected against injury from external influences.

Steel and iron are consequently chosen for boilers, pipes, engine parts, etc., as possessing sufficient hardness and strength. For example: nobody would think of making a boiler shell of lead or tin, aside from considerations of weight and cost.

Hardness is of importance, also, in wearing surfaces. It is found that cast iron, with its great hardness, is the best material for the bores, or liners, of cylinders and for the faces of the valve chest, as well as for the piston rings and valves moving on these faces. In slipper guides is found another instance in which the hardness of the cast iron proves a valuable quality.

Where form and strength must be preserved a soft material offers numerous drawbacks. Thus, it is objectionable to use lead pipes for bilge suction, as they are too easily affected by external injury. In other places, softness may prove a highly desirable quality, as in all packing materials. Here the softness of the lead, copper, rubber, hemp or putty allows a displacement of the particles against one another, under pressure, thus filling more effectively all interstices between the clamping surfaces.

758. What is understood by strength and where is it of importance?

Strength is the quality of materials that renders them capable of resisting stress.

Strength may vary according to the stresses produced in the material under different applications of load. Thus, cast iron possesses great strength, under compressive stress, but possesses much less strength under tensile stress.

For general purposes, we may consider it an approximately

accurate rule that the strength of a material is in direct ratio to its hardness.

It is, thus, found that steel, if tempered or hardened, possesses greater strength than in its ordinary state.

Naturally, it is desirable to choose the strongest materials in the construction of machinery, as the greater the specific strength, the smaller the amount needed to furnish a certain required degree of endurance and resisting quality. Iron and steel are strong materials, and, therefore, excellently adapted for use in the construction of machinery. Copper and brass, although less strong, and consequently required in a larger quantity for the same strength, come next in the scale of desirability, particularly as they possess valuable chemical qualities, rendering them comparatively immune from corrosion.

759. What is understood by toughness, and where is it of importance?

Toughness is that quality of a material by which a greater or less degree of displacement of the particles is rendered possible to the point of complete separation. Thus, a piece of copper wire, on account of its toughness, can be bent many times without breaking, while a piece of cast iron would crack or break on the first attempt at bending, because of its lack of toughness. This displacement of the particles may also be shown, upon pulling the particles apart, or pushing them against one another. Thus, the copper wire, if supporting a very heavy weight, will stretch and thin out until, at last, it may pull apart. Another example is found in a piece of lead, which, upon being hammered or pressed, spreads its particles out, forming a flat disc.

It is thus possible to distinguish between different degrees of toughness, ranging from brittle to plastic.

It may be noted, also, that, in the average, hard materials are

likely to be brittle, while the softer materials generally have a more or less plastic nature. Thus, hard cast iron and hardened steel are brittle, cracking and breaking easily, while soft copper or lead can be hammered, shaped or drawn out with great facility.

Brittleness is often an undesirable quality in materials where a readiness in stretching, or yielding under stresses, is likely to prove a valuable feature, if not present excessively. The material, through this stretching, gives a certain timely warning which, if heeded by ceasing the application of the excessive stress, may prevent serious consequences. Stretching in one direction is generally accompanied by reduction of dimensions in all other directions.

The quality of toughness may show itself also in change of shape. Thus, if the furnace of a boiler comes down and bulges without rupturing, the toughness of the material prevents a serious accident. It is for this reason that soft steel, with considerable stretching capacity, is, by many engineers, considered preferable to hard steel with less yielding capacity.

760. What is elasticity, and where is it of importance?

Elasticity is that quality of a material which enables the particles to return to their original positions, with relation to one another, after displacement. Thus, a spring, if bent or compressed by a load, returns to its original condition or length after the load is removed.

All materials possess this quality of elasticity to a greater or less degree; since under all loads there is a certain displacement of the particles due to extension, compression, twisting or bending, although this displacement may be so small that delicate measuring instruments are required for its observation.

Up to a certain magnitude of stress, the deformation of material takes place proportionately to the stress. This point

is called the elastic limit and on the average may be accepted as equivalent to one-half of the load, capable of rupturing the material.

Within this elastic limit, most materials return to their original dimensions, upon removal of the load. Beyond this point, however, the deformation of the material progresses much more rapidly than the increase of the load, and is also of a permanent character. Thus, a strip of sheet iron may be deflected back and forth without danger of permanent deformation, but if it is rolled tightly around a bar of iron it will remain permanently in the form of a coil. Another example is found in a part of a boiler head, where the material between the stays bulges, within the elastic limit, under the pressure of the steam, and returns to its original shape when the pressure is removed.

If, however, the stay breaks, the plate bulges much more, and, if strained beyond the elastic limit, the bulge will remain permanent. Shafts, in normal condition, transmit the power with a small twist, which, being within the elastic limit, leaves no effect when the power is removed. If, however, on account of a flaw in the shaft, the strength of the section is decreased, thus causing greater concentration of power, the elastic limit may be exceeded and a permanent twist will remain at the weakened section.

761. What other points are of importance in the consideration of materials?

Important points in the consideration of materials, aside from their chemical and mechanical qualities, are their cost and weight.

762. What influence is exercised by the cost of the material upon its fitness for constructive purposes?

The cost of the materials for construction of marine ma-

chinery may influence, through interest and repair charges, a pronounced degree the economy of operation of the sh propelled by the machinery.

It may thus prove advantageous to choose a cheap materi of inferior strength, rather than an expensive one of hig strength, and compensate for the defective strength by i creased thickness.

Numerous other considerations enter into such calculation For example: an expensive material may prove more desirab and remunerative, on account of its greater durability, bett wearing qualities, or immunity from breakdowns, delays and r pairs. Thus, copper or brass, although ranging from eight ten times higher in price per pound than iron or steel, are co sidered necessary for all salt-water connections, condens tubes, pump cylinders or liners and the valves and workir parts of numerous other intermittently-operated appliances the machinery. To reduce the total required amount of highe priced materials, they are frequently used only for liners working faces, over the cheaper materials.

763. What influence is exercised by the weight of the m terial upon its fitness for constructive purposes?

The weight of the material may prove important in consi ering the total carrying capacity of the ship, or questions co cerned with its propulsion. Where the total weight of the m chinery is small, in comparison with the total weight of t loaded ship, heavier materials, or larger quantities of materi of inferior strength, are often employed, if accompanied by c creased cost. Where the total weight of the machinery is p portionately large, lighter materials, or smaller quantities superior strength, are frequently employed, without great rega to cost.

To conveniently estimate the weights of different materi they are placed in comparison with fresh water, and the figu

stating how many times heavier or lighter it is than an equal bulk of fresh water is called its specific gravity. Thus zinc, being seven times heavier than water, has a specific gravity of 7.

764. What are the important materials used in the construction and operation of marine machinery?

The principal important materials used for marine machinery are:

(1.) Iron and steel.
(2.) Copper.
(3.) Copper alloys.
(4.) Tin, zinc, lead and their alloys.

765. In what forms are iron and steel employed?

Iron and steel are employed in cast or forged shapes. The readiness of application of both these metals for constructional purposes depends largely upon the percentage of their contained carbon.

According to this carbon percentage, they may be classified as:

(1.) Cast iron, with 2.5 to 3.5 per cent. carbon.
(2.) Steel, with 0.06 to 1.5 per cent. carbon.
(3.) Wrought iron, with 0.02 to 0.10 per cent. carbon.

766. What are the qualities of cast iron?

Cast iron, on account of its cheapness and its ready quality of being cast into all kinds of complicated shapes, is one of the most important materials. It possesses strength, particularly in compression, and, through its hardness, has great durability. Rust and corrosion do not affect it as greatly as they affect steel or wrought iron. One disadvantage involved in its hardness, is its brittleness and lack of toughness. These qualities render it unsuitable for receiving such shocks as, for example, may occur in the important moving parts of the engine. It can-

not be forged or drawn and its elasticity is small. While it easily melted and poured into intricate moulds, it cannot welded. However, its low price and unlimited supply, enablir it to be easily obtained and replaced, render it an extreme valuable material.

767. What kinds of cast iron are recognized?

Two kinds of cast iron are recognized, according to the form in which the carbon appears in the iron.

While molten, iron holds the carbon in complete solutio but when cooled, a part or all of the carbon may be precip tated in flaky, graphite form. The amount of the graphit thus formed, depends upon the manner of cooling. If the ca iron is cooled very gradually, all or most of the carbon becom graphitic, and little or none is combined. If, on the other han it is cooled suddenly, or chilled, little or no carbon becom graphitic, while all or most of it is combined. Very differe qualities are thus developed in the cast iron, which is gray color, and soft in structure, when cooled slowly, and contai ing all carbon in graphitic form, and white in color, and hard ar brittle in structure when chilled, and containing all carbon combined form.

The combined carbon has the greatest influence upon t value of the cast iron as a constructive material. Being infl enced by other ingredients, frequently found in the iron, changes the qualities of the iron very pronouncedly. The other ingredients are generally silicon, phosphorus, sulph and manganese.

Silicon, in small percentages, changes some of the combin carbon into the graphitic form, thus making the cast ir softer, but if present in an amount greater than three per cer it tends to make the iron brittle and weak.

Phosphorus weakens cast iron greatly, and is permissil

only in less than 1 per cent., when it may increase the fluidity of the cast iron.

Sulphur does not enter cast iron very readily, but, when present, it seems to exert an influence in reducing the carbon and silicon, and decreasing the strength.

Manganese increases the capacity of iron to hold carbon in large percentages, to about double the normal amount. It gives, also, a certain hardness and durability of surface, and decreases the magnetic qualities of the cast iron.

768. What kind of cast iron is used for constructive purposes, and where is it employed?

The gray or soft cast iron is preferred for constructive purposes, as being more easily machined and considerably tougher than white cast iron. It is most often used for cylinders and valve chests, covers, pistons, valves, columns, bed-plates, condensers, stern tubes, bearings, valve-casings, furnace fronts, grate-bars, bridge-castings and numerous smaller parts. Wherever ribs and flanges are required on the constructive members cast iron is used, as possessing the quality of most readily assuming such complicated forms in molding.

769. What special forms of cast iron are employed?

A special form of cast iron is malleable iron, produced by annealing the completed castings in a bed of oxidizing materials, which withdraw that portion of the carbon nearest to the surface. The strength, and particularly the toughness, is thereby increased, sometimes to such an extent that the part may be forged and bent without fracture.

Another special kind of cast iron, called semi-steel, may also be produced by adding to the molten mass scraps of wrought iron or steel. Through them the strength and toughness of the cast iron is increased, making it suitable for many constructive

details, which must otherwise be constructed in a more expe sive material.

770. What are the qualities of steel?

Steel is, at the present time, the most important material construction. Its low price, combined with its great streng and toughness, permits its application to the largest and mo severely-strained constructive members, both moving and st tionary. It can be forged or cast in any convenient form, ar is readily obtained in form of plates, bars, and other shapes.

A disadvantage is that it is rather readily influenced by ru and corrosion, requiring systematic and careful attention order to preserve it against the action of moisture, oxyg and carbonic acid, and insure its continued usefulness.

It is also attacked by galvanic action, in connection wi copper or brass, upon immersion in a polarizing fluid.

In regard to its percentage of carbon, steel occupies middle position between cast iron and wrought iron. In co mon with the former, it has a sufficiently low melting point f casting, and, in common with the latter, a sufficient toughne for forging

771. Which kinds of steel are recognized?

According to their varying percentages of carbon, thr kinds of steel may be recognized:

(1.) Soft steel.
(2.) Medium steel.
(3.) Hard steel.

The first variety is nearest to wrought iron in carbon p centage and qualities, being soft, readily forged, and, by ca ful handling, may also be welded. However, it lacks t quality of taking temper upon sudden cooling. It is used i great many constructive parts of the boilers and engine, prin pally the flanged and highly forged parts, furnace plat

rivets and other details, which are exposed to alternate heating and cooling, or to severe treatment by shaping and forming.

The second division, medium steel, is naturally harder than soft steel. It is also readily forged and machined, but cannot very well be welded. It will not take temper, neither will it harden upon sudden cooling in water. It is the most frequently-used material for all kinds of engine forgings, boiler shells, etc., which require no very severe treatment during manufacture.

Its stiffness renders it desirable as a material for piston rods, connecting rods, crank and other shafts, valve-stems and eccentric rods.

Cast steel may be classed with medium or soft steel in the matter of carbon percentage, although it is less easily forged, and is not so tough as these two wrought varieties. This may be due to addition of other materials, such as silicon and manganese, which are needed for the production of sound and perfect castings. Steel castings prove very valuable constructive members, and can frequently be substituted for forgings at considerably less cost. They are used for pistons, cylinder and valve chest covers, cross-heads, valve casings, columns, bearings and caps, bed-plates of high speed machinery and numerous other details.

The third division, hard steel, comes the nearest to cast iron in carbon percentage, and possesses, as its most important quality, a decided facility for tempering and hardening upon sudden cooling in water. Tempering is a modification of the extreme hardness of which the steel is capable, to the degree found best suited to the work imposed upon it. Thus, tools are made from this grade of steel, being tempered to yellow or blue, as required. For rapidly running machinery, where great strength and small weight are required, this kind of

steel offers an excellent material for piston and connectin rods, crank shafts, etc., frequently being oil-tempered c strengthened by the addition of a percentage of nickel.

772. What kinds of steel are recognized, according t methods of manufacture?

With modern methods, steel is produced by reducing th carbon percentage of cast iron to the desired amount. Th may take place in two ways by:

(1.) Bessemer process.

(2.) Open hearth process.

Another process of obtaining steel is by increasing th carbon percentage of wrought iron to the required poin This process is employed in the production of the highes grade tool steel, and consists in heating good raw material i a bed of charcoal, melting it in crucibles, and casting it int the desired shapes or forms.

773. How is steel produced by the Bessemer process?

The Bessemer process of steel manufacture consists in blo ing air into a vertical, pear-shaped converter, full of molte cast iron. The air is blown in at the bottom, and risin through the molten mass burns the carbon. If the air admi sion is arrested at the right time a steel of predetermine qualities and hardness may be obtained.

The converter is tripped on trunnions and its conten poured into molds.

The ingots coming from these molds are then rolled in plates or shapes, or forged out, as required.

Bessemer steel is objected to by some engineers, as not po sessing uniformity of qualities throughout the material o tained from the same converter. Further, it is not alwa possible to determine the exact point at which to arrest t admission of air, with consequent uncertain results.

774. How is steel produced by the open-hearth process?

The open-hearth process of steel production consists in depriving the cast iron of its surplus carbon in a shallow furnace, where the molten material is exposed, on a broad surface, to passing currents of air and gases, which burn out the carbon.

The molten mass can be mixed and stirred, and, by removing a small amount as a sample, can also be tested. By this means the reduction of carbon can be more accurately adjusted to the desired degree. The open-hearth product is regarded by many engineers as more uniform in qualities, and, therefore, preferable for most purposes.

775. What substances are frequently found in steel?

In addition to carbon, other substances such as phosphorus, sulphur, silicon and manganese, appear to a greater or less degree in steel. Steel may intentionally be mixed with certain other metals, mainly manganese, nickel, aluminum, chromium and tungsten, which may add strength, hardness or toughness, as desired.

776. What influence has phosphorus upon the qualities of steel?

Phosphorus increases the hardness and brittleness, giving the steel the quality called "cold short." The percentage of phosphorus in steel should not exceed from 0.04 to 0.08 of one per cent.

777. What influence has sulphur upon the quality of the steel?

Sulphur increases the brittleness of steel while hot, making it "red short," and interfering seriously with the shaping and forging of the material. It should not exceed from 0.02 to 0.05 of one per cent.

778. What influence has silicon upon the quality of steel?

Silicon hardens steel, and helps to avoid unsoundness in ingots and cast steel. It is not considered objectionable below 0.2 of one per cent.

779. What influence has manganese upon the quality of steel?

Manganese increases the strength, hardness and soundness of the steel. With a percentage above three, the hardness increases to such an extent that the steel can no longer be machined with ordinary tools. The durability and resistance to wear is enormous with steel containing from 3 to 14 per cent of manganese.

780. What influence has nickel upon the quality of steel?

Nickel increases both the strength and toughness of the steel. Nickel steel proves an excellent material for forgings subjected to severe stresses, as shafts, connecting rods, piston rods, etc. It is less liable to crack than steel containing no nickel, and thus lasts considerably longer.

781. What influence has aluminum upon the quality of steel?

Aluminum acts upon steel largely in the direction of improving the soundness of ingots and castings.

782. What influence have chromium and tungsten upon the quality of steel?

Chromium and tungsten increase the hardness of the steel without increasing the brittleness. Such steels are valuable for tools, as, even in an untempered state, they are hard enough to scratch glass.

783. What are the qualities of wrought iron?

Wrought iron is at the present time rarely used. It possesses less strength than steel and is more expensive. Its most valu

able quality is the readiness with which it may be welded, which quality causes it to be preferred for certain constructive details, like walking beam straps, and similar closed forgings. It is also considered desirable for boiler tubes, stay-bolts and welded braces, and has been found to resist corrosion in boilers better than steel, particularly such wasting as shows in pitting.

784. What are the qualities and the use of copper?

Copper, after iron and steel the most important material, is very soft and ductile, and can, therefore, readily be forged and drawn into sheets, tubes or wire. It can be cast soundly, with skill and precaution, but blowholes are very likely to occur.

Copper is valuable on account of its ability to be built up with pieces of intricate form from small sheets united by brazing. If well made, the brazing joints represent nearly the same strength as the solid metal, and can be bent and exposed to the same working temperature as the copper. Trouble with a brazed joint lies in the fact that copper, if heated up to nearly its melting point during the operation of brazing, loses its strength, becoming weak and brittle. When in this condition the copper is called "burnt."

Copper, by its great ductility, is an excellent material for all pipes exposed to expansion and contraction under varying temperatures. With a few bends the pipe readily adjusts itself to the new temperature and length.

For very high pressures and temperatures, copper is no longer universally employed in large pipes or fittings, as the brazing carries with it such a degree of unreliability that steel and composition take its place as safer materials. Small solid drawn copper pipes are, in extensive scale, used for conveying steam and water on board of ship.

Although copper does not corrode, it exercises a powerfully destructive galvanic action upon iron and steel, if immersed

together in a polarizing liquid, and is, therefore, not a desi able material on steel hulls, in places reached by salt water c bilge.

785. What are the qualities and uses of copper alloys?

The copper alloys are mainly mixtures of copper with tin c zinc, or with both.

An alloy of copper and tin is frequently called bronze c gun metal; one of copper and zinc is called brass, and one c copper, tin and zinc is called composition. All alloys posses ing good strength contain copper as the largest part, and, b judicious mixing, have also great toughness, rendering the highly valuable materials readily cast, drawn or forged int manifold shapes and forms.

The non-corroding quality of the copper alloys renders the highly valuable for all places where corrosion would destroy th tightness or smoothness of the joint or bearing. It is use therefore, in stuffing-boxes, valve seats and spindles, air an water-pump cylinders, pistons and valves, condenser tube plat and tubes, bushings for propeller shafts and propeller blade A great many special mixtures are in use, containing sma quantities of iron, nickel, aluminum, lead, manganese an phosphorus, for giving a desired increase of strength or toug ness.

786. What are the qualities and uses of tin, zinc, lead an their alloys?

Tin possesses a low melting point and proves valuable f fusible plugs as safeguards against overheating of the heati surface in boilers. Otherwise its principal use is as an ingr dient in the manufacture of alloys.

Zinc is a valuable material for protecting iron and ste against galvanic action. It is, therefore, used in boilers, in s

valve outlets and in other places where the steel is exposed to corrosion. It is also used in many alloys.

Lead possesses the qualities of great softness and indifference of galvanic reaction toward iron and copper. It is readily drawn into pipes that are used for bilge suction. In form of sheets or wire, it is used for packing purposes.

Alloys of lead and antimony, sometimes with additions of tin, zinc, copper or iron, prove valuable bearing metals, and are known under the names of white metal and Babbitt metal. These alloys are popular for use as bearing linings, because they can be readily applied to the bearing brass, where their softness relieves the shaft or pin of all wear.

787. How are the chemical and mechanical qualities of materials ascertained?

The qualities of materials are ascertained by tests. The chemical qualities, as well as the amounts of carbon, phosphorus, sulphur, silicon, nickel, or other admixtures, are determined by analysis performed in chemical laboratories.

The mechanical qualities, strength, toughness and elasticity, are measured, aside from special tests, by pulling a piece of the material in a testing machine.

788. What is a testing machine and how is pulling of the material performed in it?

A testing machine is an apparatus in which a piece of material can be clamped and held by supports and exposed to a very strong pull. This heavy pull is obtained from a weight acting through a system of levers which intensify the pull. The piece of material is generally of a certain accepted shape, having often a length of eight inches and a section of from one-half to two square inches.

789. What information is obtained by pulling the materia in a testing machine?

The information obtained by the pulling in the testing machine is:

(1.) Elastic limit.
(2.) Final rupturing stress.
(3.) Amount of elongation.
(4.) Contraction of the original area.

As the pulling in the testing machine takes place by th action of a weight upon a certain area of section, it is natural t express the result in pounds of stress upon an area of one squar inch. Thus, by gradually increasing the weight and pull i the machine, it is possible to find the point, or weight, at whic the extension ceases to be uniform, which is the elastic limit.

By further increasing the load, or pull, the point of rupturin weight is finally reached. By laying the broken pieces t gether, and measuring between the two marks, which wer originally eight inches apart, the elongation is found. B measurement, the area, at the place of rupture, can be dete mined for comparison with the area of the original section.

790. What are the average values of strength, elasticit and elongation found in the different materials?

The average values of the different materials are shown i the following table:

	Ultimate Tensile Strength. Pounds per sq. in.	Elastic Limit. Pounds per sq. in.	Per Cent. Elongation in 8 inche
Cast iron	15,000–30,000	5,000–10,000	
Malleable cast iron	25,000–35,000	15,000–20,000	1.5
Soft steel	50,000–62,000	32,000	25
Medium steel	62,000–74,000	35,000	22
Steel castings	60,000–70,000	35,000	10–15
Hard steel	74,000–100,000	42,000–60,000	8–18
Wrought iron	45,000–55,000	22,000–28,000	10–15
Copper	30,000	10,000	35
Composition	25,000–40,000	10,000–15,000	5–15

791. Is it desirable to submit the materials to a stress equal to the ultimate strength?

No. Materials are built into machinery for long continued usefulness and permanency of form. To resist a certain maximum stress the material is distributed in such quantities that the stress on the unit of one square inch of section is considerably less than the ultimate strength, and even considerably less than the elastic limit. The efficient performance of the engine depends upon the unchanged form of the parts, and it is, therefore, necessary to keep the load well within the elastic limit.

The builders of the machinery decide upon a working load for the unit of sectional area, generally from $\frac{1}{5}$ to $\frac{1}{10}$ of the ultimate strength, or from about $\frac{1}{3}$ to $\frac{1}{6}$ of the elastic limit. The figures, 5 or 10, by which the ultimate strength has been divided for determination of the working load, are called factors of safety.

792. What other tests are made for determining the quality of the material?

Other tests for determining the quality of the materials are:

(1.) Deflection or cross-breaking test.

(2.) Cold bending test.

(3.) Hammering and drifting tests.

793. How is the deflection or cross-breaking test made?

The deflection or cross-breaking test is made by supporting a bar of the material on two pivots, observing the deflection caused by placing weights on the middle of the bar, and increasing them until fracture finally results.

The section of the bar is frequently one inch square, while the distance between the pivots is often twenty or twenty-four inches.

794. How is the cold-bending test made?

The cold-bending text is made by bending a strip, or ba of the material back upon itself, or around a mandril, ha ing a diameter of from one to three times the thickness the piece. If the material stands the test, it will show fracture on the outside of the bent part. This test is ofte made, after the material has been heated a cherry red an then been plunged into water having a temperature of degrees Fahrenheit.

Another method used for angles or shapes is to bend th flanges of the angles together, or to flatten them out, unt they are in one plane. With good material no fracture shou occur at the corner.

795. How are the hammer and drift tests made?

Hammer tests are frequently made on pieces of rivet ste or iron, that are hammered on end, and flattened down to thickness equal to about one-half the diameter, without flaws cracks.

Drift tests are made on plates by driving conical pins in small holes, thus enlarging them and swelling the metal up to ridge around its circumference, without cracks or flaws.

796. What forms of stress must the material resist in th operation of marine machinery?

The stresses that the material must resist may appear in th following forms:

(1.) Tension.
(2.) Compression and deflection.
(3.) Shearing.
(4.) Bending.
(5.) Torsion.

All parts of the marine machinery are during operati subjected to one or the other of these stresses, often alterna

ing between one or the other, or they may be subjected to several of them at the same time.

797. How is tension stress exerted?

Tension stress tends to pull the particles of the material away from each other in the direction of the longitudinal axis, as it occurs in determining the ultimate tensile strength in the testing machine. The total stress is upon all sections of the bar or rod at the same time.

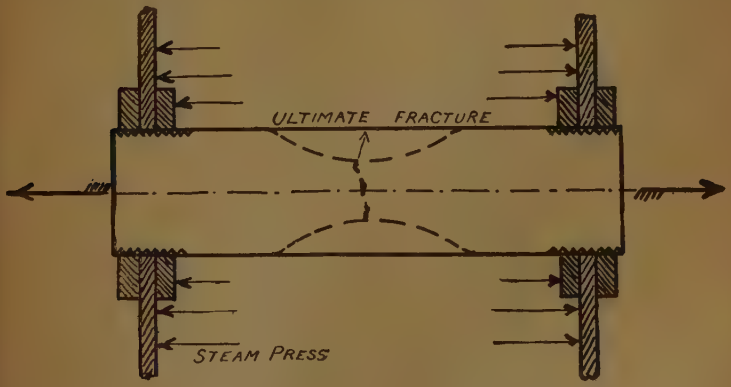


FIG. 220.—Diagram Illustrating the Action of Tension Stress, as described in Section 797.

798. In what principal positions does the tension stress exert itself in marine machinery?

The boiler braces and stay-bolts, holding the end heads together and preventing their bulging, are subject to severe tension stress.

The piston rod on the up stroke of the piston is subject to tension stress in the same way as is the valve stem on the downstroke.

The boiler shell resists tension stress, tending to pull the top half away from the bottom half, under the pressure of the steam.

When the propeller is backing, it pulls upon that part of th line shafting aft of the thrust bearing.

As an example, it may be interesting to consider a stay-bol spaced eight inches from its neighbors, thus being obliged t support eight times eight, or sixty-four square inches of plat ing. If the pressure of the steam is 100 lbs. per square inch the total load on the stay-bolt would be 6,400 lbs. If th ultimate strength of the stay-bolt material is 64,000 lbs. pe square inch, and the factor of safety chosen is ten, then th

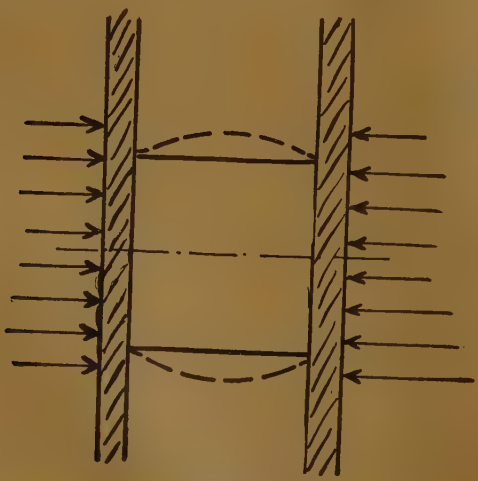


FIG. 221.—Diagram Illustrating the Action of Compression Stress, as described in Section 799.

area of the stay-bolt, at its weakest point, must be one squar inch. To realize the desired strength, therefore, the stay bolt must have a diameter of about 1⅛ inch at the botto of its thread.

799. How are compression and deflection stresses ex erted?

Compression stress tends to push the particles of the ma

terial closer together in the direction of the longitudinal axis.

If, however, the piece into which the material is shaped is very long, the particles may find it easier to move sideways, instead of longitudinally, thus deflecting the bar or rod. This will occur when the length of the rod is over about ten times its smallest transverse diameter.

The deflection stress is, generally, the most severe one in long bars, and more material must, therefore, be provided for its resistance than for resisting a pure compression stress. While the total compression stress strains all sections alike, the deflection stress exerts its maximum influence at a point about midway from the two end supports, and, frequently, the section at this point, is increased, with gradual tapering down toward the ends.

800. Which are the principal positions in which compression and deflection stresses occur?

Compression stress occurs in the furnaces of Scotch boilers, under influence of the longitudinal expansion of their material by the heat of the fire. The braces and outside shell, being more completely cooled by water, do not expand as much as the furnaces, and, therefore, compress them in longitudinal direction. Other applications of compression stress are represented by the packing between flanges, or in stuffing-boxes, in which cases the material is often strained beyond its elastic limit, with permanent change of form. The slipper guide cross-head is exposed to compression stress. Compression stress is experienced also, locally, in the walls of the furnaces and in the tubes of fire-tube boilers, condenser shells and similar closed vessels, the outside of which must endure a certain excess pressure.

Cases of deflection stress are represented by piston rods

and connecting rods during the downstroke, while eccentri rods are subjected to deflection on the upstroke of the valve The long connecting and eccentric rods of beam engines hav special provisions, by tie-rods, or lattice-work, to prevent de formation, under the deflection stress, thus making the rod stiff enough to receive and transmit the load simply unde compression.

801. How is shearing stress exerted ?

Shearing stress tends to shear the particles of the materia apart, transversely across the longitudinal axis, where the act ing and reacting influences are in one and the same plane, bu

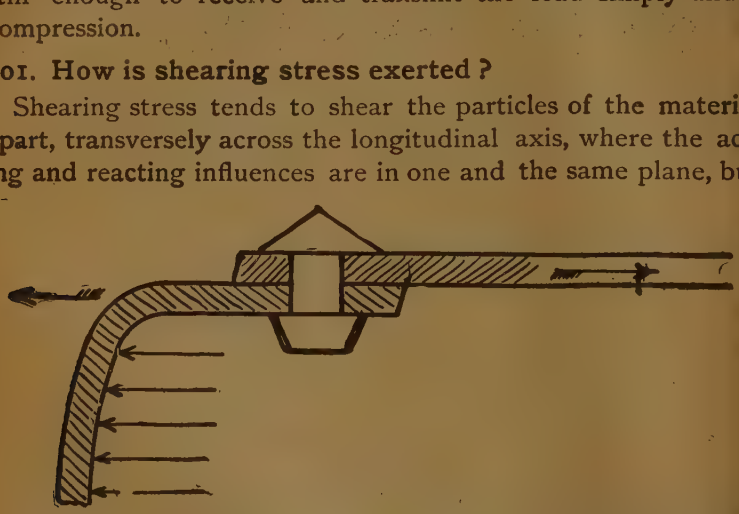


FIG. 222.—Diagram Illustrating the Action of Shearing Stress on a Boiler Rivet, as described in Section 801.

on opposite sides. The effort of the stress is concentrate entirely upon the section in this plane, without affecting an other part.

802. What are the principal positions in which shearin stress occurs ?

The principal place where shearing stress is found is in th riveted joints. Thus, the steam pressure in the drum of water-tube boiler tries to shear all the rivets in the circumfe ential seam, and to push the whole head out of the drum.

Another case of shearing stress takes place in the narro

strips of the drum sheet, outside of the rivets. If each of the pieces of plate, between the edge and the body of the rivet, should tear or shear out, the whole head would, also, be pushed out by the steam-pressure.

Shearing stress occurs in the retaining influence of screw threads.

All stay-bolts and braces attached by screw threads have a tendency to pull off the holding nut, or plate, by shearing off the threads around the circumferential plane at the bottom of the thread. Numerous similar examples are found in the retaining nuts of piston, valve, connecting and cross-head bolts, bolts of bearings, cylinder heads and in other places.

803. How is bending stress exerted?

Bending stress tends to separate the particles of the material transversely, across the longitudinal axis, and where the acting and reacting influences are not in the same plane, but are apart from each other by a certain leverage. In this case several sections experience a stress in varying proportions, depending upon their distance from the load or one or two supports.

A point of maximum stress can be found which should receive a greater amount of material to keep the working load per unit of section within a desirable limit. Less material is required for other places, but as it is often more convenient to have bars and rods of a fairly uniform section, the section of maximum stress only is proportioned for a certain working load per square inch, and the same sizes used for all other sections with a correspondingly higher factor of safety.

The stresses, under the same load, vary directly as the length between the supports, or as the distance from the load to the support, and also directly with the breadth of the beam, but they vary in the second power of the depth of the beam.

For example: A bar one inch wide by one inch deep, supported on two knife edges, twenty inches apart, can carry twenty pounds of load in the middle of its length with a factor of safety of ten. This same bar can support forty pounds of load, with the same factor of safety, if the knife edges are only ten inches apart, or it would have a factor of safety of 20 if only twenty pounds of load were placed upon it in this position of the supports. If the length of twenty inches remains and the bar is increased in width to two inches, then the weight may be increased to forty pounds, or the factor of safety runs to 20, with the same load. But if the bar is increased to two inches of depth, retaining one inch of width, it is

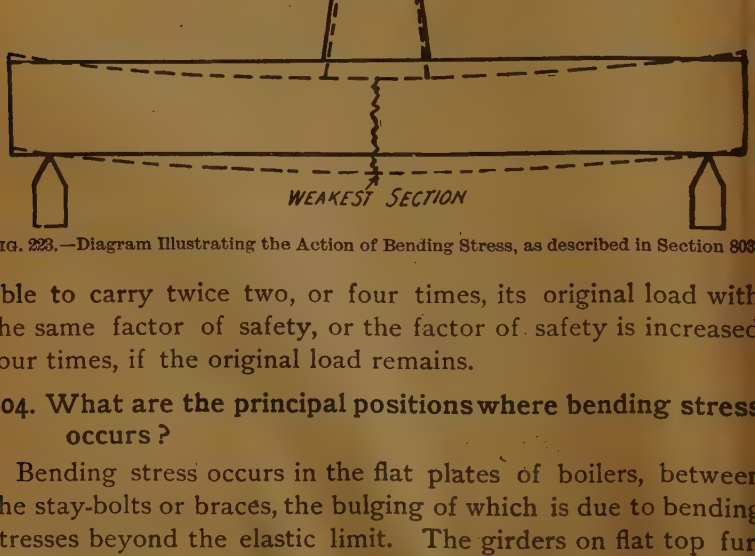


FIG. 223.—Diagram Illustrating the Action of Bending Stress, as described in Section 803

able to carry twice two, or four times, its original load with the same factor of safety, or the factor of safety is increased four times, if the original load remains.

804. What are the principal positions where bending stress occurs?

Bending stress occurs in the flat plates of boilers, between the stay-bolts or braces, the bulging of which is due to bending stresses beyond the elastic limit. The girders on flat top furnaces and combustion chambers are also subject to bending stress.

In the engine, numerous parts are subject to bending

stresses, such as the cylinder heads and the pistons, the crank-shaft, the propeller blades, at their connection to the hub, and in numerous other places.

805. How is torsion stress exerted?

Torsion stress tends to separate the particles of the material by a circumferential twist around a shaft, upon which the acting and reacting forces exert their influence at the end of a lever or crank arm. In this case all sections of the shaft experience the same stress, and all shafting is, therefore, of fairly uniform diameter, except where subjected to combined stresses.

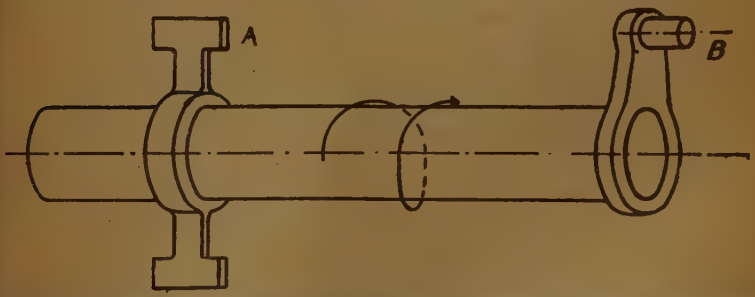


FIG. 224.—Diagram Illustrating the Action of Torsion Stress, as described in Section 805. A is a fan wheel; B, the crank on the shaft.

The stress varies inversely in proportion to the third power of the diameter. Thus a shaft two inches in diameter can stand a torsional moment eight times larger than a shaft one inch in diameter, or it has a factor of safety eight times larger, with the same torsional moment.

806. What are the principal places where torsion stress occurs?

Torsion stress occurs principally in all shafting. Other examples are valve spindles, upon which the hand-wheel exerts a torsional stress, most severely in the closing position, while

at the same time a compression, or deflection, stress is exerted upon the spindle, through the wedging action of the screw threads.

807. What forms of combined stresses occur in marine machinery?

There are manifold possibilities in marine machinery for combination of stresses.

A valve spindle may thus be subjected, at the same time, to compression and torsion stresses. A crankshaft is an example of a combination of bending and torsion stresses. The crank webs are subjected to changing bending stresses, eccentric compression stresses, and torsion stresses.

It is, of course, necessary to determine, as closely as possible, the stress that will strain the materials most severely, and proportion the amount of material to suit this maximum stress.

All steel bars to be used as stays or braces in marine boilers and allowed a stress of 7,000 8,000, or 9,000 pounds per square inch of section, tested by the United States assistant inspector at the mills where the material is manufactured, shall be tested in the following manner: There shall be taken from each heat two pieces for tensile tests and two pieces for bending tests. The full-size bars within the capacity of the testing machine may be used for tensile tests. When the full size of the bar is too large for the capacity of the testing machine, the bar may be reduced in size to meet such capacity. To facilitate and insure accurate tests, all bars for tensile and bending tests may be reduced in size. The minimum tensile strength of each test piece shall be not less then 58,000 pounds per square inch of section and each test piece that has been reduced in size shall show an elongation of at least 28 per cent in 2 inches. Where the full size of the bar has been used for testing, the test piece shall show an elongation of at least 25 per cent in 8 inches. When the tensile strength of the test piece is more than 63,000 pounds per square inch of section, each test piece that has been reduced in size shall show an elongation of at least 26 per cent in 2 inches. Where the full size of the bar has been used for testing, each test piece shall show an elongation of at least 22 per cent in 8 inches. The pieces for the bend test shall be bent cold to a curve, the inner radius of which is equal to one and one-half times the diameter of the bar without flaws or cracks. Should any such test bar fail in either the tensile or bending test, no bars from such heat shall be allowed to be used in the construction of any marine boiler. Where a heat of steel bars has been passed by an inspector, separate lots of bars from such heat may be furnished to different boiler manufacturers upon a certificate from the mill that the bars were made from such accepted heat.

CHAPTER TWENTY-EIGHT

STEAM TURBINES

The development of the steam turbine was caused chiefly by the demand for a higher rotative speed, due to the introduction of the dynamo. Originally the dynamo ran much faster than the engine, the speed reduction being accomplished by means of a belt drive with pulleys of unequal diameters.

The problem which naturally presented itself to designers of dynamos and engines was how to reduce the speed of the dynamo, and increase that of the engine so the two could be directly coupled. This resulted in the introduction of the short stroke or "high speed" engine, capable of running with great rotative speed. On account of the large clearance space, due to the short stroke, these engines were not very economical in the use of steam; this, together with the disadvantages of running reciprocating engines at high rotative speeds caused inventors to turn their attention to the turbine. The problem now was reversed, that is, it became a question of how to increase the speed of the dynamo, and reduce that of the turbine sufficiently for a direct connected unit.

Principle of the Turbine.—The operation of a turbine is *due to centrifugal force* produced by changing *the direction of a jet of steam escaping from a nozzle at high velocity.* This is done by so placing the nozzle that the jet will impinge on numerous curved vanes attached to a wheel free to revolve, thus causing rotation.

The kinetic energy of the steam is considerable, for although its weight at ordinary pressures is very small in proportion to its volume, the velocity of

steam escaping from a nozzle is very great. For instance, at 180 lbs. gauge pressure, steam flowing directly into the atmosphere has a velocity of about 3,000 feet per second, or 3,700 feet per second when flowing into a vacuum.

The principle of turbine operation may be more clearly presented by aid of a diagram, figure 225. V, V′, are curved vanes attached to the circumference of a disc, or *rotor* W. At one side, and placed at an acute angle with the rotor, is a steam nozzle. In operation, steam issuing from the nozzle at high velocity, has its direction changed by the curved vanes, it being obvious that if it enter in the direction shown by the arrows, it will leave its course as indicated.

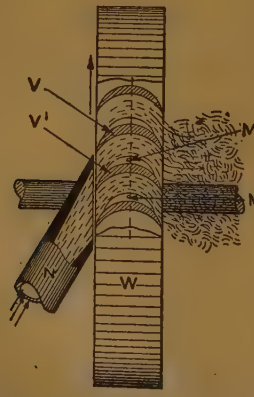


FIG. 225.—Diagram showing principle of ***turbine operation***. Steam issues from the nozzle N, at high velocity, and on striking the curved vanes its direction is changed; the centrifugal force thus set up tends to cause the wheel to rotate in the direction of the arrow. This action is caused by *impulse* up to the dotted line, and by *reaction* beyond that point to the end of the vane. The usual application of the words "impulse" and "reaction" is erroneous and misleading. The pressure between the vanes is the same as the pressure within the casing in which the wheel runs. With the vanes constructed as shown, there would be spaces M, M′, not filled by the steam, since the area of the passages at these points is greater than at the entrance and exit. Some manufacturers, however, make the blades thicker at the center than near the edges, to maintain a constant area and so avoid possible eddy currents.

The steam, in flowing through the curved passages, causes the wheel to rotate, due to *impulse* in flowing from the entrance to the dotted line, and to *reaction* in flowing from this point to the end of the passage.

It must be obvious that the rotation of the wheel is caused by centrifugal force acting against the forward vanes, and *not by the pressure of the steam.* For, if the curved passages be closed, thus bringing the steam to rest, it would press equally against the vanes, V, and V′; since these present equal areas, there would be no excess force tending to cause rotation.

If the blades were made as shown, the area of the passages would not be uniform and there would be spaces as at M,M′, not filled with steam. Hence, in practice, blades are made thicker at the center than at the ends.

Classification.—Turbines may be classified in several ways; a common, yet erroneous division being with respect to the action of the steam, as:

1. Impulse;
2. Reaction.

Both words, as used in this connection, are mis omers, and therefore misleading, as will later be explained.

With respect to whether there be one or more revolving discs, or *rotors*, in one *compartment* turbines are called:

1. Simple;
2. Compound;

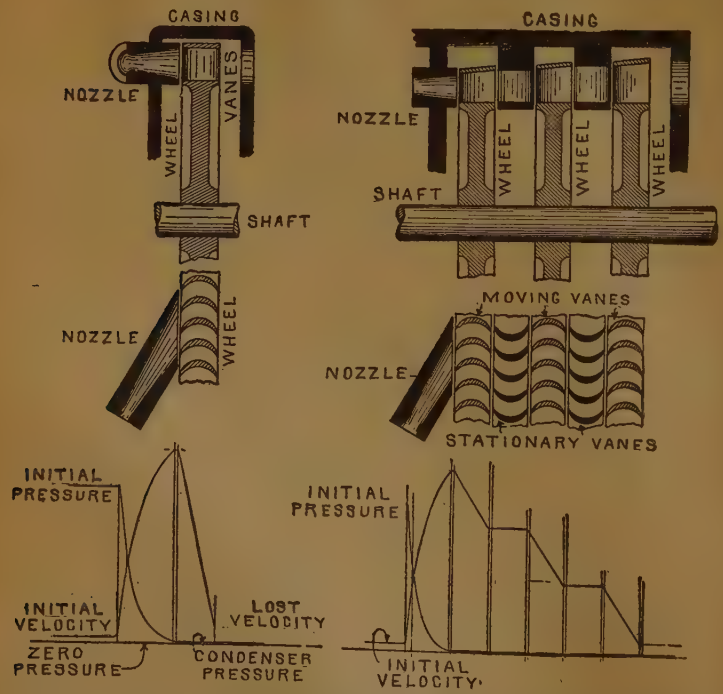
and with respect to the number of step reductions of pressure, they are classified as:

1. Single stage;
2. Multi-stage.

There are also several divisions depending on the direction in which the steam flows, as:

1. Radial { inward flow; / outward flow;
2. Axial, or parallel flow;
3. Mixed flow.

Impulse and Reaction.—Giovanni Bianca, of Lorreto, Italy, in the year 1629 invented a turbine very much like a miniature



FIGS. 226 to 228.—Simple impulse turbine and pressure velocity diagram. ***In operation,*** the steam is completely expanded in the nozzle, being reduced to condenser pressure at the outlet. The velocity falls in passing through the wheel, a certain amount of energy being lost by the inability of the wheel to absorb all the velocity generated in the nozzle.

FIGS. 229 to 231.—Compound impulse turbine and pressure velocity diagram. Steam after leaving the nozzles, passes through several wheels separated by sets of stationary valves. As with the simple turbine, the steam is completely expanded within the nozzles, issuing therefrom at condenser pressure. The velocity generated in the nozzles is absorbed in steps as the steam flows through the wheel, and remains constant during the passage through the stationary vanes. The object of compounding is to reduce the speed of rotation.

water wheel, as shown in figure 232, and operated by a jet of steam; this represents a simple and pure *impulse* wheel.

In a book written by Hero, of Alexandria, in the year 100 B. C., a very simple form of pure reaction turbine is described. As shown in figure 233, it consisted of a hollow sphere, free to rotate on two trunnions, through one of which it received steam from a boiler. The sphere was provided with two opposite projecting nozzles, at right angles to the axis of the trunnions, and pointing in opposite tangential directions. The reaction of the steam escaping from the nozzles caused the sphere to revolve on its trunnions, in much the same way that water escaping from the arms of a lawn sprinkler causes it to revolve.

The two turbines just described are presented simply to illustrate the operation of a turbine by impulse and by reaction. **All modern turbines, although grouped into two classes, as impulse and reaction, operate by the combination of these two forces.**

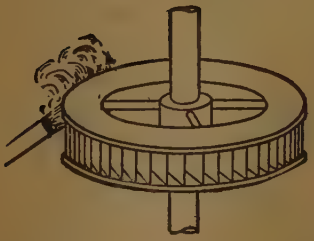


FIG. 232.—The first impulse turbine; invented by Giovanni Bianca, of Loretto, Italy, in the year 1629. *Pure impulse operation.*

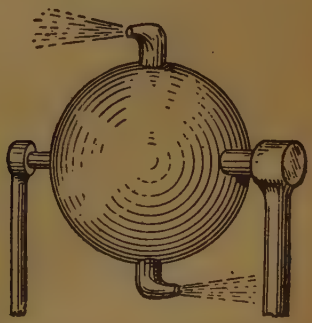


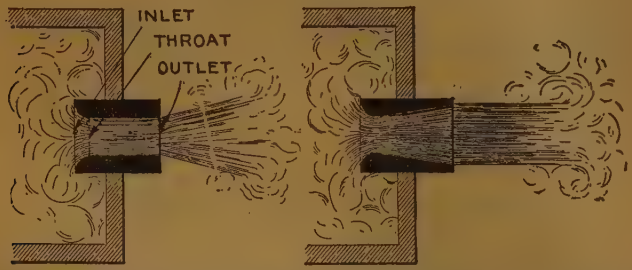
FIG. 233.—Ancient reaction turbine, as described by Hero of Alexandria in the year 100 B. C. *Pure reaction operation.*

Figure 236 shows the usual type of blades in the so called impulse turbine, and figure 237, the necessary shape for impulse alone, without any reaction. Figure 238 shows what is known as a reaction turbine. By comparing figures 236 and 238 it will be seen that the operation of these wheels is, in each case, due to both impulse and reaction. The distinction between the two types depends on the shape of the nozzle and vanes.

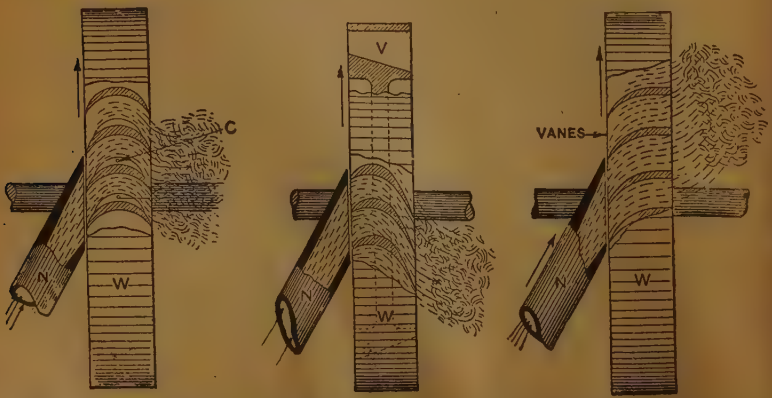
The use of the terms "impulse" and "reaction" is unfortunate,

but since their misapplication has become general, it is necessary to understand the significance as applied to turbine operation.

In the so called impulse type, figure 236, the nozzle is of a diverging cross section, allowing the steam to expand therein; it thus attains a high velocity, and impinges upon the moving vanes. The steam, in passing through the wheel, imparts some of its kinetic energy to the blades, and leaves them at a lower velocity, but *at the same pressure* at which it left the nozzle.



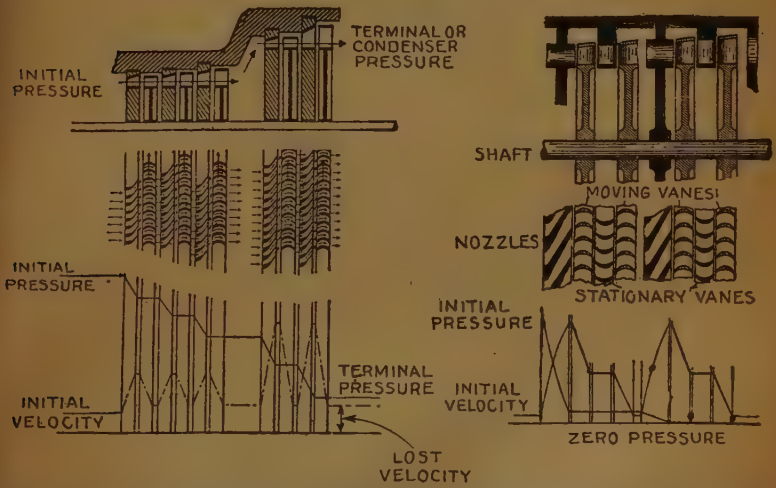
FIGS. 234 and 235.—***Parallel*** and ***diverging*** nozzles. ***The distinction*** between the two is that expansion of the steam takes place after discharge from a parallel nozzle, and before discharge in a diverging nozzle. In the first case, the discharge takes the form of a conical jet and in the second that of a cylinder. The velocity is greater with a diverging nozzle since it is not reduced at discharge by lateral expansion.



FIGS. 236 to 238.—Elementary turbines illustrating ***impulse*** and ***reaction***. Fig. 236, so called impulse wheel; fig. 237, pure impulse wheel in which there is no reaction; fig. 238, so called reaction wheel.

In the so called reaction type, fig. 238, the nozzle has parallel sides, hence the steam passes through it at practically constant pressure, expansion taking place during its flow through the wheel. The passages are of diverging cross section to permit this expansion, *thus reducing the pressure.* It is important to note from the foregoing that:

In the impulse type, *steam enters and leaves the passages between the vanes at the same pressure.*



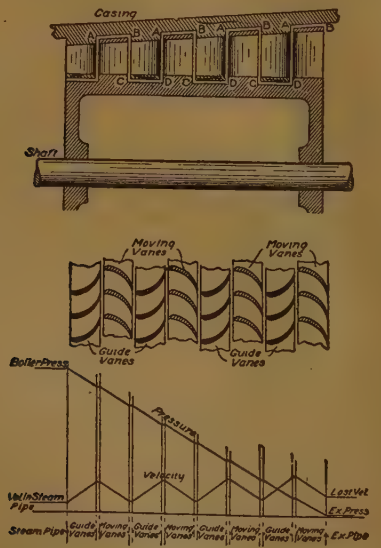
FIGS. 239 to 241.—Simple multi-stage impulse turbine and pressure velocity diagram. The word "stage" relates to working pressure. In a multi-stage turbine, steam, in passing through the turbine, works at several pressures. There is a separate compartment and set of nozzles for each stage; the pressure of the steam is constant in passing through a compartment, but drops successively as it passes through the several sets of nozzles, regenerating velocity at each reduction of pressure. Modern multi-stage turbines sometimes have as many as twenty to thirty stages.

FIGS. 242 to 244.—Compound multi-stage impulse turbine and pressure velocity diagram. It is virtually two or more compound turbines joined in series, or the equivalent, a multi-stage turbine having more than one wheel in each compartment. The object of compounding is to reduce the number of stages, especially in case of high initial pressure.

In the **reaction type;** *the pressure is less on the exit side of the vanes than on the entrance side.*

Expansion is confined to the nozzle in the impulse type, and to the vane passsage in the reaction type.

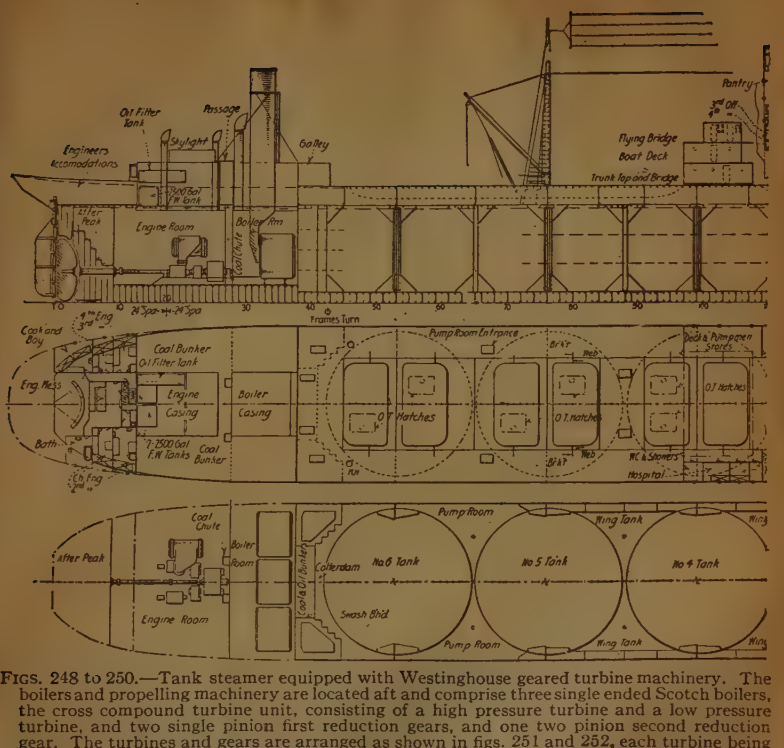
Reaction Turbines.—Usually, turbines of this type are built compound, as shown in figs. 245 to 247; the principal parts consist of numerous rows of moving vanes, separated by alternate rows of fixed guide vanes. The passages through the latter are of increasing cross section, hence part of the expansion takes



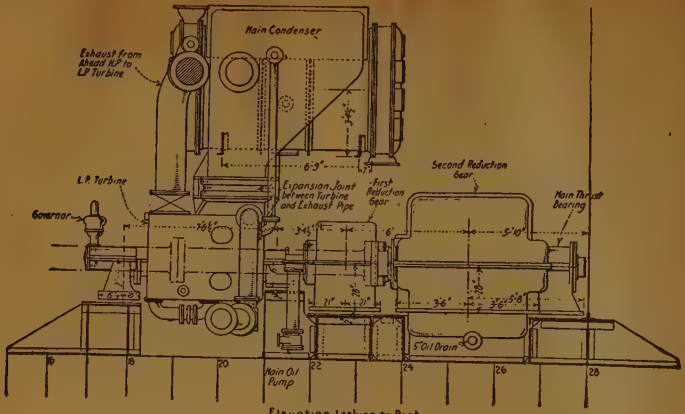
FIGS. 245 to 247.—Compound reaction turbine. In this type steam expands in passing through the moving vanes instead of in the nozzle, as with the impulse turbine type. The pressure falls gradually from inlet to outlet.

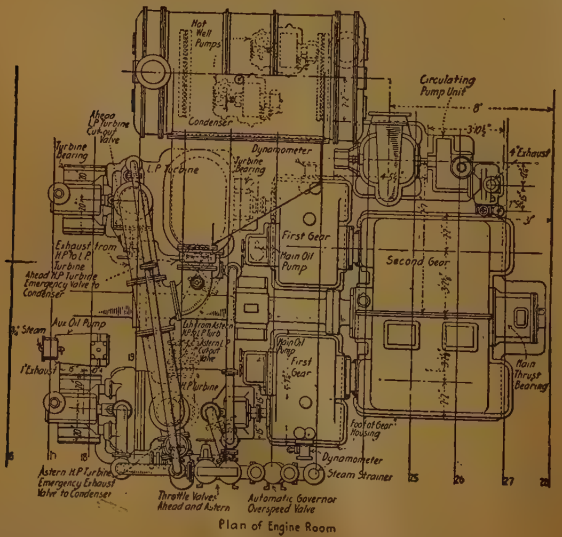
part therein, being completed in the wheel. It should be noted that the fixed guides perform the functions of nozzles, and the steam in passing through the turbine expand continually from boiler pressure to exhaust pressure.

The diagram indicates the increase of velocity as the steam flows through the guide vanes, and the decrease in passing through the adjacent moving vanes. The pressure falls gradually from the inlet to the outlet; it is, therefore, maintained higher in the turbine passages than the exhaust pressure, this being characteristic of the reaction principle.



FIGS. 248 to 250.—Tank steamer equipped with Westinghouse geared turbine machinery. The boilers and propelling machinery are located aft and comprise three single ended Scotch boilers, the cross compound turbine unit, consisting of a high pressure turbine and a low pressure turbine, and two single pinion first reduction gears, and one two pinion second reduction gear. The turbines and gears are arranged as shown in figs. 251 and 252, each turbine being coupled to one of the first reduction gears, which in turn are coupled to the second reduction gear, this latter gear being directly connected to the propeller shaft. By means of this arrangement of double reduction gears, comparatively high speed turbines are utilized for driving a slow speed propeller. The propeller thrust bearing is of the Kingsbury marine type and located at the forward end of the second reduction gear. The condensing equipment consists of a surface condenser, a geared turbine driven centrifugal circulating pump, two turbine driven centrifugal hot well pumps and two Leblanc air ejectors. The lubrication of the main turbine bearings and the gear teeth and bearings is effected by a continuous supply of oil through a gravity system. Two oil pumps driven off the gear shafts, a cooler, strainer and storage tank, also comprise part of the oil system. The oil is discharged from the oil pumps into an overhead tank from which it flows by gravity to the system. An auxiliary steam driven oil pump is also installed. Seatings for the turbines and gears are of the usual plate and angle construction built up from the engine room floors. The arrangement of steam piping shown diagrammatically in fig. 263 is such that while the turbines are designed to operate primarily as a cross connected combined unit, each turbine may be operated independently on high pressure steam, thus providing two separate sources of power for use in an emergency. The normal speed of the ship is 10.5 knots, the displacement being, as given above, 12,650 tons. When the turbines are operating with dry saturated steam at a pressure of 180 pounds gauge at the throttle valve, on 28½-inch vacuum (barometer 30 inches), the following conditions will obtain: Speed of ship, 10.5 knots; *r.p.m.* of propeller, normal, 70; R. P. M. of turbine, normal, 3,600; S. H. P.—ahead, normal, 2,500; S. H. P.—astern, maximum, 1,740.





FIGS. 251 and 252.—Elevation and plan of engine room of steamers *Malmanger* and *Golaa*, showing general arrangement of Westinghouse turbine machines. The cylinders are lagged where necessary with non-conducting material, and the lagging is covered with a sheet metal jacket, which permits easy access to the turbine joints. Relief valves are located in the ahead and astern receiver pipes. The lifting gear is composed of I-beam girders and chain hoists above the turbines and gears and special slings and guides are provided for lifting the rotors without injury to the blading. A hand ratchet lever which operates on ratchet teeth cut on the flange of the coupling is provided for turning the turbine, for adjustment and inspection.

Marine Equipment.—The application of steam turbine with reduction gears for ship propulsion is well exemplified in the machinery installations of tank and freight steamers. Geared turbine propelling machinery may be located in the stern of the vessel as has been found expedient in the case of oil tankers, or its location may be amidships which is usual for cargo ships. The geared turbine machinery as applied to tank steamers of the "Malmanger" and "Golaa" class will be taken as typical,

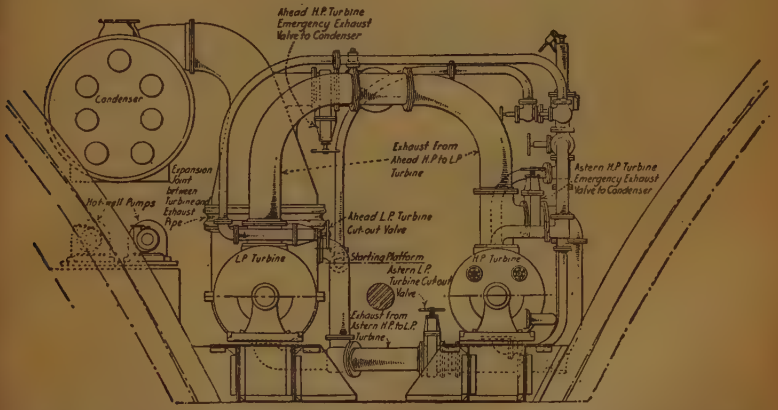

Ahead H.P. Turbine Emergency Exhaust Valve to Condenser
Condenser
Exhaust from Ahead H.P. to L.P. Turbine
Astern H.P. Turbine Emergency Exhaust Valve to Condenser
Expansion Joint between Turbine and Exhaust Pipe
Hot well Pumps
Ahead L.P. Turbine Cut-out Valve
L.P. Turbine
Starting Platform
H.P. Turbine
Astern L.P. Turbine Cut-out Valve
Exhaust from Astern H.P. to L.P. Turbine

FIG. 253.—Cross section through engine room of steamers *Malmanger* and *Golaa*, showing general arrangement of Westinghouse turbine machinery. The weights of the principal parts are: Turbines, 37,000 lbs.; reduction gears, thrust bearing and oil pumps, 86,300 lbs.; condenser, 21,600 lbs.; condenser auxiliaries (consisting of circulating pump, condensate pump and air ejectors), 9,250 lbs.; oil filter tank, oil cooler, oil storage tank, auxiliary oil pump, 6,500 lbs.; cross-connecting piping and main exhaust connection, 29,100 lbs.; total weight 189,750 lbs., or 84.71 tons; weight per shaft horse power, 75.9 lbs.

and the description which follows will serve to illustrate late practice in marine turbine machinery.

Turbines—The turbines are of the combined impulse reaction cross compound type and are shown in section in figs. 254 and 255, each element being fitted with both ahead and astern features. The turbine cylinders consist of base and cover.

The main bearing pedestals at the exhaust end of the cylinders form part of the base. The pedestal at the inlet end of each turbine is a separate casting bolted on to the cylinder base. This latter pedestal carries the governor and also accommodates the thrust bearing. At the exhaust end of the cylinder base, the bearing pedastals are rigidly bolted down to the seating. At the

inlet end of the turbine, the bearing pedestal is supported on a cast steel soleplate, which is bolted to the seating. Guides are bolted to this soleplate, to permit the pedestal to move horizontally. This arrangement allows freedom for expansion of the turbine cylinder in the fore and aft direction.

The ahead high pressure nozzle chamber forms an integral part of the turbine cylinder. The astern high pressure nozzle chamber is a separate steel

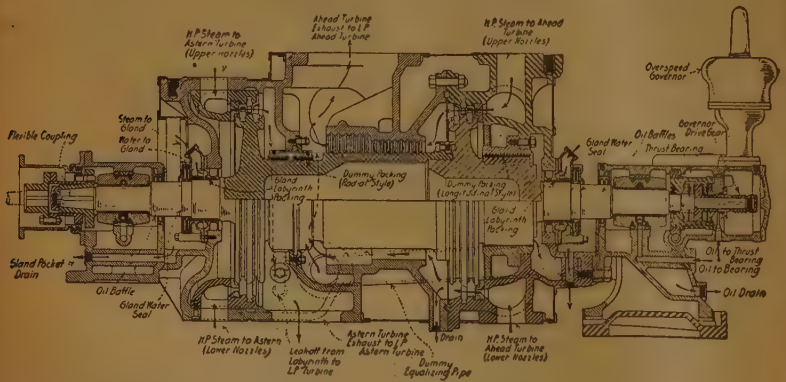


FIG. 254.—Cross section of Westinghouse high pressure turbine.

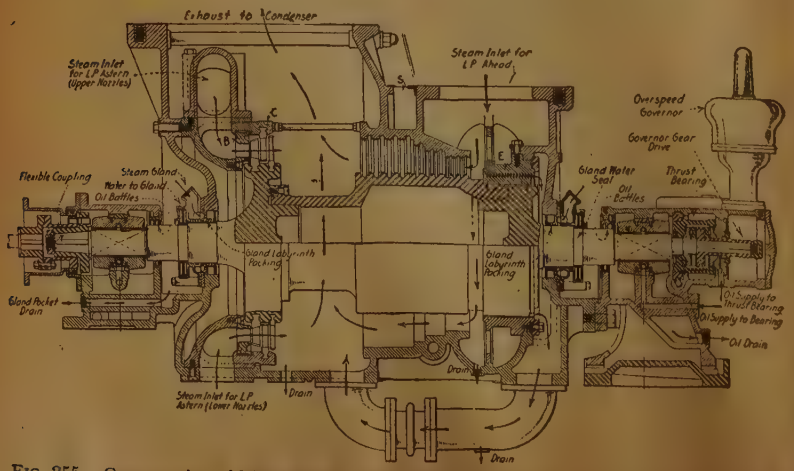


FIG. 255.—Cross section of Westinghouse low pressure turbine.

casting bolted in the exhaust end of the high pressure turbine. There is no nozzle chamber in the ahead end of the low pressure turbine. The low pressure astern nozzle chamber is located in the exhaust end of the low pressure cylinder and is made of cast iron. It is of the same construction as the high pressure astern nozzle chamber, and is bolted in position. The high pressure and low pressure astern nozzle chambers in the upper and lower halves of the turbine cylinder are separate pieces and are each provided with steam inlet and outlet.

All nozzles are of the diverging type cast in bronze blocks and are secured to the nozzle chamber by means of wedges and screws. The upper high pressure nozzle chamber is divided into three compartments, two of which are provided

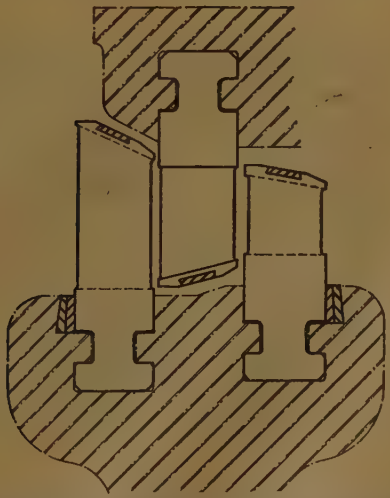


FIG. 256.—Westinghouse impulse blade construction. The impulse blades are of machined nickel steel and have a machined shank which fits into a groove cut in the spindle. To secure the blades against vibration, they are wedged into the groove by specially formed wedges. The top of blades carry a dovetail groove, into which a binding strip is driven and afterwards welded.

with hand operated valves for use when the turbines are operating at partial load. With this arrangement of nozzle control, all, five-sixths or three-quarters of the nozzles can be brought into operation as required. The astern nozzles are not arranged for group control, as great economy at reduced astern power is of little importance.

The turbine rotors and shafts are made of steel. The impulse wheels are integral parts of the shaft; the rotors and shafts are bolted together on the largest diameter permissible. This construction is clearly shown in figs. 255 and 254. The length between the bearings is short and the construction is very stiff giving smooth and safe operation.

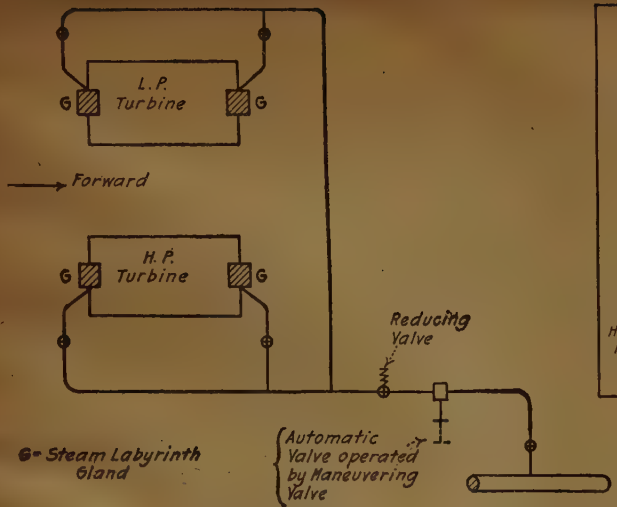
Blading.—The blading is made up of two different forms. The first two rows in the high pressure turbine are of the impulse type, the remaining ahead blades in the high pressure, and all the ahead blades in the low pressure turbine being of the reaction type. The astern blading in both the high pressure and low pressure turbines consists of two rows of impulse blades.

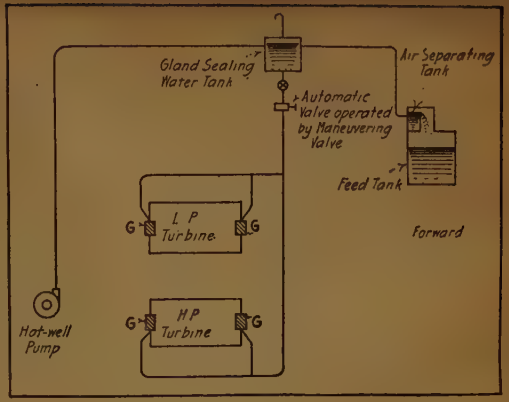
Balance Pistons or Dummies.—To balance the end thrust on the spindle, due to the action of the steam on the blades, balance pistons have been provided at the inlet end of the turbine. The stationary part of the balancing arrangement is secured to the cylinder, and the rotating portion is shrunk onto the turbine spindle and has grooves cut in it. In the stationary part are brass or aluminum strips fitted into grooves, these strips projecting into the grooves

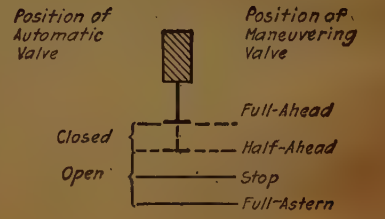
FIGS. 257 to 259.—Westinghouse reaction blading. It is made from drawn phosphor bronze. The method of attaching reaction blading is clearly shown in the figure, a supplementary groove being provided in the bottom of the main groove which receives an upset foot on the blades. This upsetting operation increases the thickness of the whole lower portion of the blades, adding to their area about 40 per cent, tapering off to the standard section some distance above the surface of the blade carrying element. This thickening is not clearly shown in the illustration. Dovetailed packing pieces come between the blades, the forged foot of the blades coming beneath the packing pieces providing an interlocking system with which no caulking is necessary, making it possible to replace blades without mutilation of the blade carrying member. Lashing wires in sufficient number are provided for bracing the upper ends of the blades, the number of these lashings depending on the dimensions of the blades.

of the rotating portion. The location and arrangement of the balance piston is shown in figs. 254 and 255, and which also show the connection from the exhaust space at the end of the reaction blades to the space behind the balance piston. By means of this connection the steam thrust on the spindle can be wholly or partially balanced, depending on the diameter of the balance piston.

High Pressure Intermediate Gland.—This gland is located in the high-pressure cylinder, between the low pressure end of the reaction blades and







FIGS. 2?0 to 2.2.—Diagrams of Westinghouse steam seal piping, water seal piping, and operation of automatic valve. The steam seal portion consists of a labyrinth packing similar in desig ı to the high pressure intermediate gland. This portion of the gland utilizes steam as a means of sealing against leakage, and is in use up to half speed, after which the water sealing portion of the gland automatically comes into operation. This latter element consists of a centrifugal runner shrunk and doweled on the turbine spindle and running in a chamber contained in the body of the gland. The runner is equipped with radial webs and operates as a centrifugal pump with zero delivery. At half speed and above the runner will, when supplied with water, maintain a solid ring of water at its periphery, effectively sealing the turbine against leakage. A drain is provided so that any water which may leak out of the gland is collected and discharged to the feed tank. The steam supplied to the glands is taken from the main steam line through a reducing valve, which regulates the pressure to about five pounds gauge. Water is supplied to the gland from a gravity tank, which receives the discharge from the condensate pump before it passes to the feed tank. The tank is located above the level of the glands to give a pressure of about 5 pounds per square inch at the glands. The supply of steam or water to the glands is automatically controlled by the manœuvring valve, as shown in fig. 266.

the astern impulse wheel, to prevent steam leaking into the astern chamber when the turbine is running ahead, and in like manner to prevent the leak in the other direction when the turbine is running astern.

This gland is made of bronze and is held in position by a clamp ring. It is grooved to take bronze or aluminum packing strips, which are held out toward the spindle by means of flat springs.

The packing strips come close to the rotor between the baffle rings which are turned on the body of the rotor. The baffle rings and packing strips interrupt the flow of steam in its endeavor to pass the packing, thus minimizing steam leakage between the two portions of the turbine.

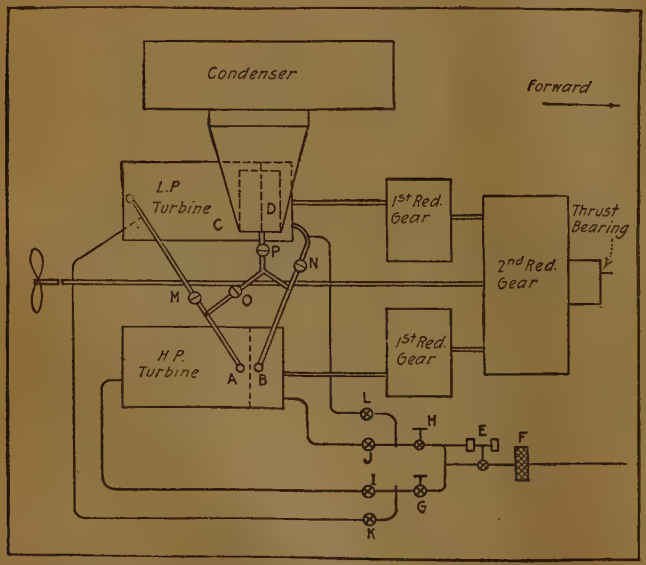


FIG. 263.—Diagram of Westinghouse steam piping and valves of marine turbine.

An annular space is provided from which the leakage past the first rows of packing strips passes to a suitable connection on the low pressure turbine.

Glands.—In order to prevent steam leakage from the turbine to the atmosphere, or air leakage into the turbine, a combined steam and water gland is used at each end of the cylinder, as shown diagrammatically in figs. 260 to 262.

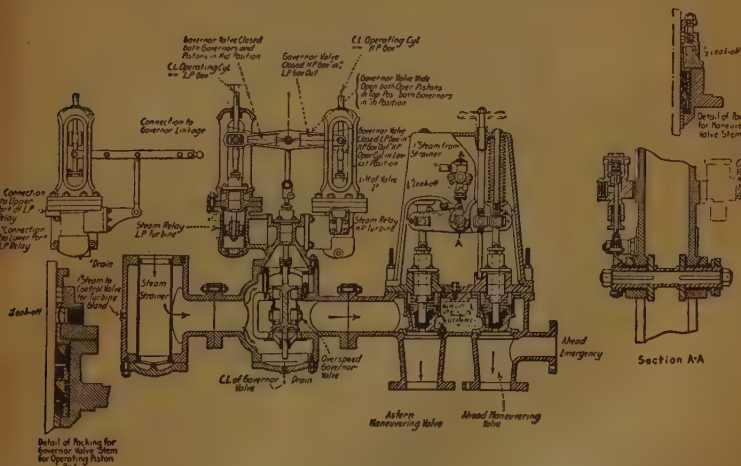
Bearings.—The main bearings are self-aligning and are fitted with removable pads and liners, by means of which the position of the turbine spindles may be adjusted either vertically or horizontally.

The outer shells of the bearings are of cast iron and the lining is Babbitt.

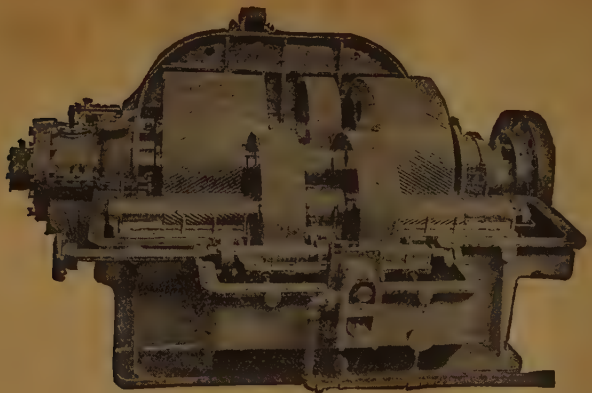
Oil is fed to the bearings under pressure, being admitted through a passage drilled in the bottom pad and liners, and conveyed to the top of the bearing by means of a tube which is cast in the babbitt lining the outlet from this tube being at the top of the bearing. The bearing housings and covers are fitted with oil guard rings, which prevent any leakage of oil along the spindle, and also exlude dust.

Thrust Bearings.—The turbine thrust bearings are of the Kingsbury segmental type. The bearings are double ended, to take thrust in either direction. The segments or shoes are babbit faced, and fitted at the back with spherically faced hardened steel buttons. These buttons rest on hardened steel pieces inserted in a spherically seated base ring.

Drain Piping.—All parts of the turbine and piping in which water is likely


Governor Valve Closed both Governors and Pistons in Air Position
C.L. Operating Cyl. — L.P. Gov.
C.L. Operating Cyl. — H.P. Gov.
Governor Valve Closed H.P. Gov. in L.P. Gov. Out
Governor Valve Body
Connection to Governor Linkage
Steam from Strainer
Steam Relay L.P. Turbine
Steam Relay H.P. Turbine
Drain
Steam to Control Valve for Turbine Gland
Steam Strainer
Overspeed Governor Valve
C.L. of Governor Valve
Drain
Astern Maneuvering Valve
Ahead Maneuvering Valve
Ahead Emergency
Section A-A
Detail of Packing for Governor Valve Stem for Operating Piston Rod
Detail of Packing for Maneuvering Valve Stems
Control Valve for Water Pit Turbine Gland

FIGS. 264 to 268.—Sectional views through Westinghouse steam strainer, governor, and manœuvring valve. A perforated sheet steel cylindrical strainer in a cast shell is fitted in the steam line between the boilers and the turbine valves. The governor valve is of the double disc balanced type, operated by two steam relay pistons. The operation of the relay pistons and the opening and the closing of the valve are controlled by the turbine governors, as previously described. The high pressure turbine governor controls one of the relay cylinders and the low pressure governor the other. The operation of either piston will close the valve. Under normal operating conditions the governor weights are held in against their stops and the valve is wide open. Should the speed of either turbine element reach the overspeed for which the governor is set, the weights move out and cause the valve to close sufficiently to prevent further increase in speed. With this arrangement, the turbine is not shut down completely and is always under direct control of the maneuvering valves. The ahead and astern maneuvering valves are contained in a single body, and are of the balanced single disc type, with a pilot valve on the valve stem for automatically equalizing the pressure in opening. Springs are provided above the valves to prevent them chattering in the current of steam. The valves, balance cylinders and pilot valves are of bronze. Both valves are operated by a single hand wheel. In the "stop" position both valves are held closed by their springs, and by the unbalanced pressures above the pistons. The automatic valves for the gland sealing steam and water are operated by cams attached to the yoke as shown. The main high pressure steam piping is of steel, and the low pressure receiver piping between the turbines and the main exhaust pipe is of cast iron.



FIGS. 269 and 270.—Westinghouse combined reduction gears as used in ships having engine room located amidships, the turbines being placed forward of the gears. The gearing for the two-speed reduction is contained in one housing as shown.

to collect are connected by drain pipes to a steam ejector, which delivers this water into the condenser. The ejector is necessary on account of the condenser being located at a higher level than the turbine. In order to prevent undue stress on the turbines, all pipes are arranged to allow free expansion, and where necessary, expansion joints are fitted.

Turbine Shaft.—This is connected to the flexible shaft of the pinion by means of a pin coupling which permits the pinion to move endwise. Provision is made for lubricating the pins and bushings.

Governor.—An emergency overspeed governor is located forward of the thrust bearing, and is driven from the turbine shaft by spiral gears. The governor is of the centrifugal type and controls the governor valve in the main

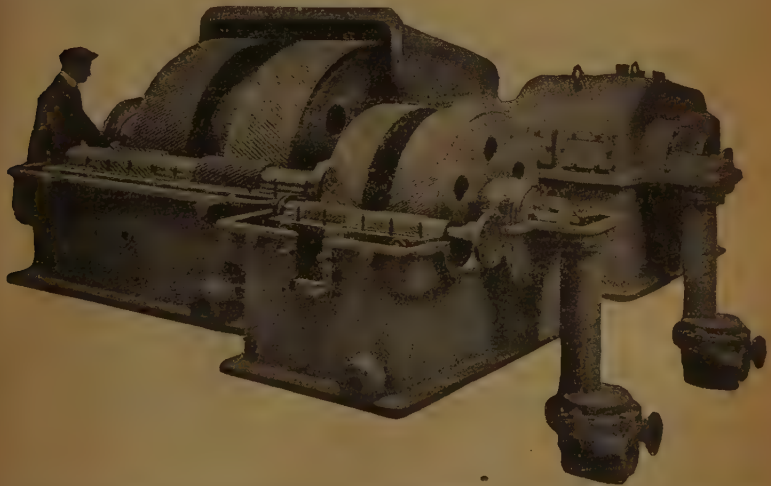


FIG. 271.—Westinghouse first and second reduction gears as applied to geared turbine equipment for ships having their engine rooms located aft. With this arrangement, the gears are placed forward of the turbines, and the intermediate shaft passes between the turbines, enabling the tail shaft to be drawn inboard for inspection without displacing any part of the turbines or reduction gears.

steam line by means of a steam relay. A floating lever and pilot valve are located on the governor. Steam from the pilot valve is led to the relay cylinder which operates the governor valve.

Turbine Valve Gear and Steam Piping.—The arrangement of the turbine steam valves and piping is shown in figs. 251 to 253, and diagrammatically in fig. 263. There is also shown in fig. 266, a cross section of the steam strainer governor valve, and ahead and astern manoevuring valves.

Reduction Gears.—These gears are of the flexible frame type and are shown in the above figure. At the designed full power, the first or high speed gears

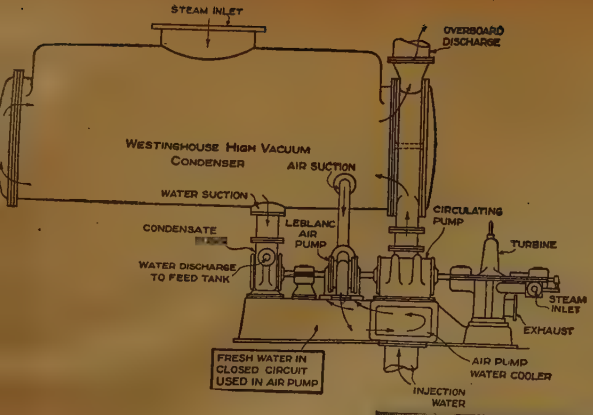
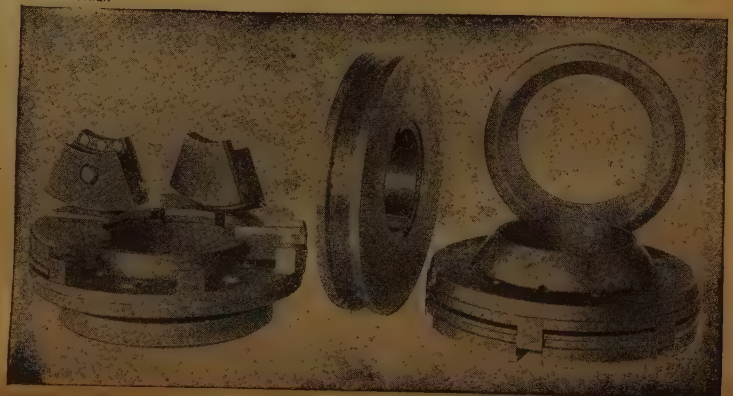


FIG. 272.—Westinghouse marine type condenser complete with pumps.

GS. 273 to 275.—Parts of Kingsbury pro-peller thrust bearing. On the turbine end of the thrust bearing cage is turned a square thread. Meshing with this thread is a nut on the outer periphery of which are cut worm teeth. This worm wheel nut is rotated by a worm placed horizontally under the worm wheel and operated by hand from a spindle which passes to the outside of the thrust bearing pedestal. The worm wheel nut rotates in a groove bored in the thrust bearing pedestal and cannot move axially. When it is necessary to move the turbine spindle axially to adjust the clearance at the dummy piston, the worm nut is revolved, causing the Kingsbury thrust bearing to move the turbine spindle fore and aft as desired.



reduce the speed from 3,600 to 450 *r.p.m.* and transmit 1,250 horse power each. The second or low speed gear reduces the speed from 450 to 70. Each pinion transmits 1,250 horse power. The total speed reduction from the turbine speed of 3,600 *r.p.m.* to the propeller speed of 70 *r.p.m.* gives a ratio of 51.4 to 1.

The gears are completely enclosed in an oil tight cast iron gear housing, and are of the double helical type, the teeth being inclined at an angle of 30 degrees. The teeth are of involute form and are cut with precision to obtain reliable and quiet operation.

The pinions are of the three bearing type and are carried in a floating frame, which automatically maintains the alignment of the pinion and gear under all conditions of load, thereby producing uniform distribution of the pressure over the entire length of tooth face. Each pinion is driven by a flexible shaft which

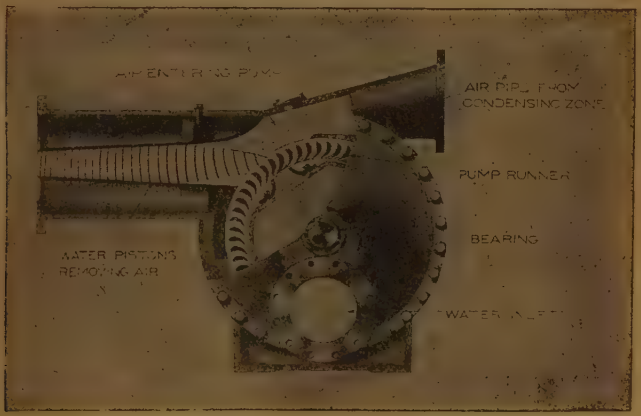


FIG. 276.—Diagram showing principle of operation of Leblanc air pumps. ***In operation,*** a continuous stream of rapidly moving layers of water are projected into the air chamber, condensing the vapor present and cooling and concentrating the air which is imprisoned between the pistons and carried out through the discharge nozzle, during which process it is compressed to atmospheric pressure. The water pistons have no clearance and there are no reversals and consequently losses due to these causes. ***The marine type*** Leblanc air pump uses fresh water in a closed circuit, which has an overflow to the feed tank. The condenser is so designed that the condensate cannot enter the air pump suction, and practically all vapor is condensed and removed from the air during its passage through the vapor remover before it enters the pump. A small surface cooler is used to remove from the air pump water the small amount of heat generated by the friction of the water in the pump and passages.

extends through it and is secured to the end remote from the coupling. The pinion coupling permits the pinion to move endwise. The flexible shaft allows the pinion to adjust itself without restriction to maintain its alignment with the gear wheel. The uniform distribution of pressure at all loads made possible by the use of the flexible frame permits the use of higher pressures and smaller pinions and gears than is the practice with reduction gears of the fixed bearing

The flexible frames are of rigid construction to avoid deflection, and are supported by feet under the middle bearing, this support being amply flexible to permit the required movement in a vertical plane. The ends of the flexible frame are held in the correct vertical plane by horizontal struts. The frames are divided and bolted together horizontally, a longitudinal channel for supplying oil to the pinion bearings and teeth being formed in the joint.

The gear wheels are composed of a heavy forged steel shaft, a cast iron center and steel rims.

The gear and pinion bearings are composed of heavy cast iron bodies lined with genuine Babbitt. The bearings are supplied with oil at a pressure of about 5 pounds per square inch which is introduced at the sides. No oil piping is contained in the gear housing. A trough which is supplied with oil from the

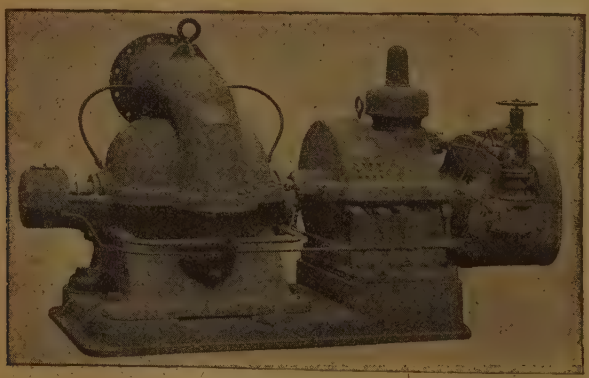


FIG. 277.—Westinghouse circulating pump. ***In construction*** the pump body is of cast iron and provided with a double inlet. The rotor is of bronze and with the gear wheel is mounted on a bronze lined steel shaft which is carried in three bearings. Glands with flax packings, provided with a water seal are fitted over the shaft at each end of the pump casing. The reduction gear is of the double helical type. The pinion shaft is extended to carry the automatic stop governor. The governor which is driven from the pump shaft is carried in the gear housing. The turbine is of the high speed impulse wheel type. It has a single row of blades, and by utilizing a reversing chamber, the steam is made to pass through the wheel twice. The turbine cylinder is cast iron. The wheel is forged steel, with fitted milled blades. The nozzle block and the reversing chamber are bronze. The shaft is provided with water sealed glands. The governor controls the speed of the turbine at full speed by means of a balanced valve, at lower speeds, control is effected by means of hand operated valves. The turbine spindle and pinion form one piece and is supported by three bearings in the gear housing, the turbine wheel being overhung. The turbine and gear bearings as well as the gears themselves are supplied with a continuous supply of oil from the main lubricating system, the gear and pinion teeth being lubricated by oil sprays directed upon them from above.

channel in the floating frame distributes the oil to the teeth from above as shown. Oil is supplied to the teeth from below by sprays which are directed against the back of the pinion from the channel in the frame, the oil being carried around with the pinion and drawn into the meshing teeth.

Propeller Thrust Bearing.—This is of the Kingsbury segmental type, and is mounted on the second gear shaft at the forward end of the gear. It is contained in a housing which is part of the second gear case as shown in fig. 271.

The thrust block consists of a steel thrust collar which is keyed to the gear shaft and held in place by a nut, and which rotates between two sets of Babbitt faced thrust shoes. As in the case of the turbine thrust bearing, the shoes are fitted at the back with a hardened steel button. The buttons rest on hardened steel pieces in spherically seated base rings. One base ring takes the thrust when going "ahead," the other when going "astern." Mounted in this way the bearing can adjust itself to any position of the shaft and each shoe always takes an even share of the total thrust. In addition the independent adjustment on the hardened steel buttons possible with each shoe permits a perfect oil film to exist between the Babbitt faces and steel collars. This increases the

FIG. 278.—Westinghouse condensate pump. ***In construction*** the impeller is bronze fitted on the end of a steel spindle which extends through the pump casing and carries the turbine rotor. The pump casing is of bronze and the portion of the spindle contained in the pump casing is enclosed in a bronze sleeve. The pumps are fitted with water sealed glands to prevent leakage along the shaft. The turbine is of the single wheel impulse type, similar to the one that drives the circulating pump. The rotor is carried in two ring oiled bearings, and the pump impeller is overhung. The turbine is equipped with labyrinth steam packed glands. The turbine shaft is extended to carry a centrifugal governor which operates a balanced throttle valve and so controls the speed of the turbine. The turbine is designed to operate on a steam pressure of 150 pounds gauge with a back pressure of 5 pounds per square inch.

efficiency of the bearing and permits the use of much higher unit pressures than are possible with the old type of horse shoe collar thrust block. The bearing is always flooded with oil in circulation, this being an essential feature for its satisfactory performance.

Main Oil Pumps.—Two oil pumps shown at the lower right hand, fig. 271, are provided for the entire equipment. Each pump is driven by means of spiral gears from the gear shafts of the high speed gears. The pumps are of the spur gear type and are located near the bottom of the drain tank. They are

arranged to operate when the turbines and gears are moving either ahead or astern.

Condensing Equipment.—The condensing equipment is entirely Westinghouse apparatus, and consists of a condenser, geared driven centrifugal circulating water pump, turbine driven centrifugal condensate pumps and air ejectors.

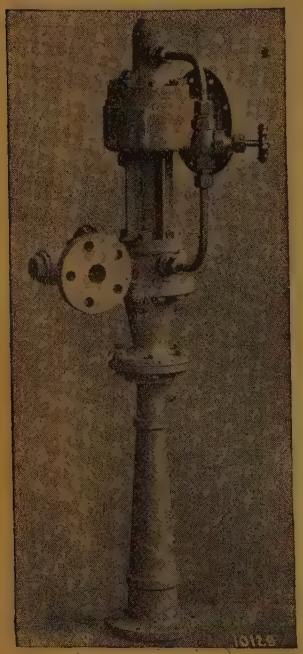


FIG. 279.—Westinghouse Leblanc air ejector. ***In operation,*** the air is withdrawn by means of multiple jets of steam in series which compresses the air to atmospheric pressure. The mixture of air and steam passes into the air ejector tank, where the steam is condensed and the air escapes to the atmosphere. By using air ejectors in place of air pumps, a very much simpler arrangement is obtained, which besides requiring less attention in operation, takes up considerably less space. The ejectors are made of bronze and the tank of steel plate. The estimated consumption of steam for each ejector is 800 pounds per hour, and the weight of each ejector is 97 pounds.

The condenser is of the surface type arranged for three passes. The tubes are ⅝ outside diameter and are 8 feet 6 inches long between the tube plates.

The whole equipment is designed to maintain 28½ inches vacuum. (Bar. 30 inches) with 65 degrees Fahrenheit cooling water.

Circulating Pump.—This is of the centrifugal type as shown in fig. 277, and is driven by a geared turbine. The arrangement allows of both the turbine and the pump to be operated at their most economical speed.

The pump has a normal capacity of 2,900 gallons per minute, and at this capacity requires 20 horse power to drive it. The maximum output of the pump is 5,500 gallons per minute.

The turbine is designed to operate with steam at a pressure of 150 pounds per square inch and 5 pounds back pressure.

Condensate Pumps.—There are two pumps for extracting the condensate from the condenser. One pump is of sufficient capacity to handle the condensate up to maximum power; the other being a standby for emergency use.

The pumps are of the centrifugal type as shown in fig. 278.

Air Ejectors.—Two Westinghouse Leblanc Air Ejectors, shown in fig. 279 are installed to extract the air from the condenser. One ejector is sufficient to meet full load conditions, the other being standby.

Lubricating System.—This is shown diagrammatically in fig. 280. Oil is supplied to the gears and turbines under a pressure of about 5 lbs. per square inch from a gravity tank.

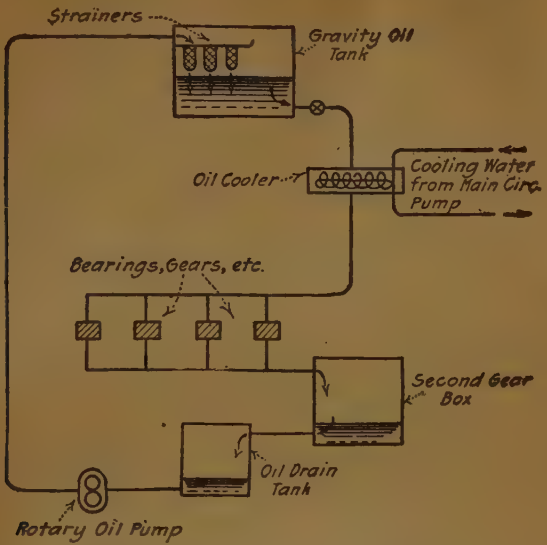


FIG. 280.—Diagram of lubrication system. The gravity tank shown in the diagram is fitted with muslin bags through which the oil is strained. The oil then flows through an oil cooler, and thence to the various bearings and the gear teeth, finally discharging into a drain tank. The rotary oil pump then delivers it from the drain tank into the gravity tank and so completes the system. When the installation is stopped or running slowly, the independent steam driven auxiliary oil pump is used to maintain the oil flow. The drain tank and oil gravity tank are of sheet steel.

CHAPTER TWENTY-NINE

LIQUID FUEL

The many advantages of liquid fuel or fuel oil for use with steam boilers have been apparent for a long time, and, in localities where the crude oil or refuse from distillation could be obtained cheaply (or where coal is very expensive) it has been used with much satisfaction.

Petroleum is practically the only liquid fuel sufficiently abundant and cheap to be used for the generation of steam. It possesses many advantages over coal and is extensively used in many localities.

There are three kinds of petroleum in use, namely those yielding on distillation: 1st, paraffin; 2nd, asphalt; 3rd, olefine. To the first group belong the oils of the Appalachian Range and the Middle West of the United States. These are a dark brown in color with a greenish tinge. Upon their distillation such a variety of valuable light oils are obtained that their use as fuel is prohibitive because of price.

To the second group belong the oils found in Texas and California. These vary in color from a reddish brown to a jet black and are used very largely as fuel.

The third group comprises the oils from Russia, which, like the second, are used largely for fuel purposes.

In general, of what does crude oil consist?

It consists of carbon and hydrogen, though it also contains varying quantities of moisture, sulphur, nitrogen, arsenic, phosphorous and silt.

NOTE.—The light and easily ignited constituents of petroleum, such as naphtha, gasoline and kerosene, are oftentimes driven off by a partial distillation, these products being of greater value for other purposes than for use as fuel. This partial distillation does not decrease the value of petroleum as a fuel; in fact, the residuum known in trade as "fuel oil" has a slightly higher calorific value than petroleum, and because of its higher flash point it may be more safely handled. Statements made with reference to petroleum apply as well to fuel oil.

The moisture contained may vary from less than 1 to over 30 per cent, depending upon the care taken to separate the water from the oil in pumping from the well. As in any fuel, this moisture affects the available heat of the oil, and in contracting for the purchase of fuel of this nature it is well to limit the per cent of moisture it may contain. A large portion of any contained moisture can be separated by settling and for best results, sufficient storage capacity should be supplied to provide time for such action.

What is the calorific value of petroleum?

A pound of petroleum usually has a calorific value of from 18,000 to 22,000 *B. t. u.*

What are the relative values of oil and coal as fuels?

Under favorable conditions 1 pound of oil will evaporate from 14 to 16 pounds of water from and at 212 deg.; 1 pound of coal will evaporate from 7 to 10 pounds of water from and at 212 deg.

The following tables show the comparison in more detail:

Relative Values in Coal and Oil

Petroleum residuum	19,500
Beaumont crude	18,500
Anthracite coal—East Middle coal field	13,400
Semi-bituminous—Cumberland, Maryland	14,400
Pocahontas, Virginia	15,070
Bituminous—Jackson County, Ohio	13,090
Hocking Valley, Ohio	12,130
Missouri coal	12,230
Alabama coal	13,500
McAllester coal, I. T.	12,789
New Mexico	12,000
Texas Lignite	10,000

These calorimeter values are carefully selected averages and furnish a means of comparing the different coals one with another, but in comparing liquid fuels with the solid, such as oil with coal, they do not form an accurate measurement of the relative value of the two kinds of fuel as steam makers, owing to imcomplete combustion due to inefficient firing and other causes.

Combustion of Oil.—Every chemical combination produces heat. Combustion or burning is a rapid chemical combination of the fuel with oxygen. The chief elementary constituents of fuel are carbon and hydrogen. Sulphur is generally present, but

its heat producing power is small and generally not considered. Substances combine in certain proportions only and these proportions are well known to chemists.

What is the behavior of oxygen in combustion?

Oxygen while itself not combustible is a supporter of combustion by combining chemically with the constituents of the fuel.

Comparative Evaporation of Coal and Oil

Taken from the United States Geological Report on Petroleum

One Pound of Combustible	Pounds of Water Evaporat's at 212 deg. per Pound of Combustible	Barrels of Petroleum required to do same amount of Ev'p'rat'n as one ton of Coal
Petroleum 18 to 40 deg. Baume		
Pittsburg lump and nut, Penna.	10.0	4.0
Pittsburg nut and slack Penna.	8.0	3.2
Anthracite, Penna.	9.8	3.9
Indiana block	9.5	3.8
Georges Creek lump, Maryland	10.0	4.0
New River, West Virginia	9.7	3.8
Pocahontas lump, West Virginia	10.5	4.2
Cardiff lump, Wales	10.0	4.0
Cape Breton, Canada	9.2	3.7
Nanaimo, British Columbia	7.3	2.9
Co-operative, British Columbia	8.9	3.6
Greta, Washington	7.6	3.0
Carbon Hill, Washington	7.6	3.0

What is necessary for complete combustion?

If the proper amount of air be introduced into the furnace and in such a manner as to bring the oxygen in intimate contact with the fuel, complete combustion takes place.

The carbon and oxygen combining and forming carbonic acid and the hydrogen combining with the oxygen and forming steam.

Carbonic acid is composed of one part by weight of carbon and two parts of oxygen.

The quantity of oxygen required for the combustion of any fuel can be readily determined when the composition of the fuel is known. As the quantity

of oxygen in a given quantity of air is known the quantity of air necessary for combustion can be easily computed.

What is the effect of an insufficient quantity of air?

Incomplete combustion takes place and the resultant gas is carbonic oxide, composed one part of carbon and one part of oxygen.

This gas is combustible and if before leaving the furnace an additional quantity of oxygen be mixed with it at sufficiently high temperature, secondary combustion takes place, the carbonic oxide combining with the oxygen and forming carbonic acid which is not combustible.

FIGS. 281 and 282.—***Cause of smoke.*** When the supply of oxygen is insufficient to consume the particles of solid carbon they are set free and then assume the form of soot, the collection of these minute particles being called smoke. This can be illustrated by cutting a hole in a card, fig. 281, so as to fit over an ordinary gas burner. Now, light the gas and place a glass chimney over the burner, letting it rest on the card. The flame will at once begin to smoke, because very little air can then come in contact with the flame, and, therefore, when the fine particles of carbon are set free by the combustion of the hydrogen, instead of being burned, as they would be if the air with its supply of oxygen were not excluded from the flames by the chimney, they escape unconsumed in the form of black powder or soot. If the chimney be raised from the card, as in fig. 282, so as to permit air to enter space between them at the bottom of the chimney to permit air to enter, as indicated by the arrows, and supply the flame with oxygen, the smoke will cease, as the particles of carbon are then consumed. The same principle is illustrated in an ordinary kerosene lamp. It is well known that without a chimney the flames of nearly all such lamps smoke intolerably, whereas with a glass chimney and the peculiarly formed deflector which surrounds the wick, the light burns without smoke unless the wick be turned up high. The effect of the chimney is to produce a draught which is thrown against the flame by the deflector, and thus a sufficient supply of oxygen is furnished to consume all the particles of carbon, whereas, without the draught produced by the chimney, the supply of oxygen is insufficient to ignite all the carbon, which then escapes in the form of smoke or soot. It must not, however, be hastily assumed that if the flame do not give out a bright light, therefore the combustion is not complete. As has already been stated, the light of the gas flame is due to the presence of burning particles of solid carbon, which is set free by the combustion of the hydrogen with which it is combined. After it is separated from the hydrogen it immediately assumes a solid form.

What is the effect of too much air?

If a surplus of air be introduced, complete combustion takes place, but some of the heat of combustion is taken up in heating the surplus air and consequently the heat available for making steam when the furnace is under a boiler is reduced in proportion to this surplus.

Can complete combustion be accomplished in practice by a quantity of air just sufficient theoretically to affect the chemical combination?

No.

The carbonic acid formed cannot instantly be removed and unless a surplus of oxygen be present to dilute the carbonic acid, combustion will not be continuous.

What is necessary to burn fuel oil?

The fuel must pass into a gaseous state before being burned.

What must be mixed with the fuel when it passes into the gaseous state?

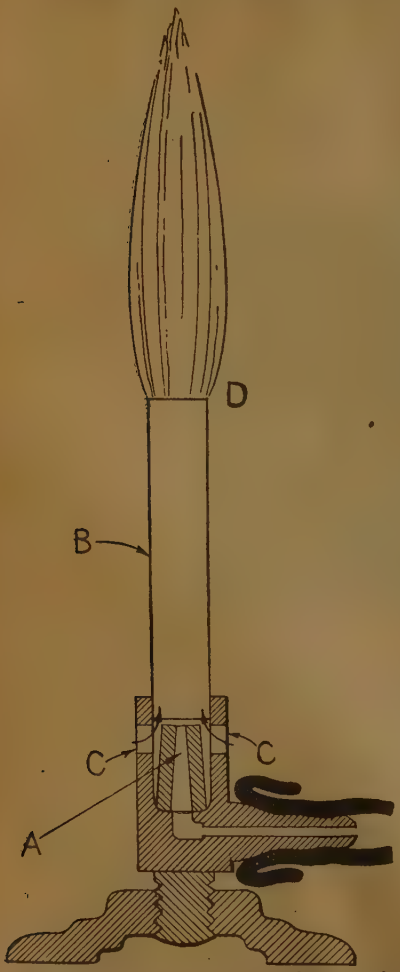


FIG. 283.—Bunsen burner. It consists of a small tube or burner A, which is placed inside of another larger tube B. The latter has holes CC, a little below the top of the small tube. The current of gas escaping from the small tube draws the air in through the holes CC, and produces what is called an *induced current* of air in the large tube. This air enters through the holes CC, and is mixed with the gas in the tube B, and the mixture is burned at D. The flame from such a burner gives hardly any light, but the heat is intense, as is shown if a metal wire be held in it for a few seconds, which will very soon glow with heat.

Air. If immediately upon assuming the gaseous state they are mixed with a large quantity of air they are completed burned with a transparent flame producing carbonic acid and steam. When raised to a red heat before receiving a sufficient quantity of air for complete combustion, carbon is disengaged in a fine powder and the higher the temperature the greater is the proportion thus disengaged.

FIG. 284.—The candle flame. It is seen to consist of three concentric cones. 1, the innermost around the wick, appearing almost black; 2, the next emitting a bright white light, and 3, the outermost being so pale as to be scarcely visible in broad daylight; there is also apparent a bright blue cup surrounding the base of the flame. 1, The dark innermost cone consists of the gaseous combustible to which the air does not penetrate, and which, therefore, is not in a state of combustion; 2, In the second or luminous cone combustion is proceeding, but it is by no means perfect, being attended by the separation of a quantity of carbon, which couples

What is smoke and soot?

If, during combustion, some of the carbon be cooled below the temperature of ignition before coming in contact with oxygen

luminosity upon the part of the flame. The presence of free carbon is shown by depressing a piece of porcelain upon this cone when a black film of soot is deposited. The liberation of the carbon is due to the decomposition of the hydrocarbons by the heat, which separates the carbon from the hydrogen, and this latter, undergoing combustion evolves sufficient heat to raise the separated carbon to a white heat, the supply of air which penetrates into this portion of the flame being insufficient to effect the combustion of the whole of the carbon; 3, the pale outermost cone or *mantle* of the flame in which the separated carbon is finally consumed may be termed the cone of perfect combustion, and is much thinner than the luminous cone, the supply of air to the external sheil of flame being unlimited and the combustion therefore speedily effected; 4, the bright blue cup surrounding the base of the flame is formed by the perfect combustion (without any separation of carbon) of a small portion of the hydrocarbons owing to the complete admixture of air at this point.

it constitutes while floating in the gas, ***smoke,*** and when deposited on solid bodies, ***soot.***

If the carbon be maintained at the temperature of ignition and supplied with oxygen sufficient for its combustion, it burns while floating in the inflammable gas and forms red, yellow or white flame. The flame from fuel is the larger the more slowly its combustion is effected.

Requirements for Burning Oil Fuel.—There are several conditions which must be fulfilled to obtain satisfactory results.

1. Its atomization or vaporization must be thorough.

This requirement is met by the selection of a proper burner.

2. When atomized it must be brought into contact with the requisite quantity of air for its combustion, and this quantity must be at the same time a minimum to obviate loss in stack gases.

3. The mixture must be burned in a furnace where a refractory material radiates heat to assist in the combustion, and the furnace must stand up under the high temperatures developed.

4. The combustion must be completed before the gases come into contact with the heating surfaces or otherwise the flame will be extinguished, possibly to ignite later in the flue connection or in the stack.

5. There must be no localization of the heat on certain portions of the heating surfaces or trouble will result from overheating and blistering.

The foregoing requirements are fulfilled:

1. By the selection of a proper burner.

2. By properly introducing the air into the furnace, either through checkerwork under the burners or through openings around them, and by controlling the quantity of air to meet variations in furnace conditions.

3. By installing a furnace so designed as to give a sufficient area of heated brickwork to radiate the heat required to maintain a proper furnace temperature.

4. By giving ample space for the combustion of the mixture of atomized oil and air, and a gas travel of sufficient length to insure that this combustion be completed before the gases strike the heating surfaces.

5. By the adoption of a suitable burner in connection with the furnace, meeting the other requirements. A burner must be used from which the flame will not impinge directly on the heating surface and must be located where such action cannot take place. If suitable burners properly located be not used, not only is the heat localized with disastrous results, but the efficiency is lowered by the cooling of the gases before combustion is completed.

Oil Burners.—There are a great variety of burners, and they may be classified in several ways.

1. With respect to the gasifying process, as:

   a. Vaporizers.
   b. Sprayers.

2. With respect to the atomizing agent, as:

   a. Air;
   b. Steam.

FIG. 285.—***Drooling*** burner. The oil to be atomized passes out and down from the upper passage, where it meets air or steam issuing from the lower passage, and being caught by the rapidly escaping and expanding air or steam is thoroughly sprayed.

3. With respect to the method of spraying, as:

   a. Outside mixing { drooling; atomizer; projector; centrifugal;
   b. Inside mixing { chamber; injector; centrifugal.

What is an outside mixing burner?

One in which oil and atomizing agent meet outside the burner.

Drooling Burner.—The oil supply simply drools or oozes out, at the orifice over and on to the steam or air jet as in figure 285. *In operation*, as the steam or air issues forth it expands within the layer or film of oil which is being carried into the furnace.

Atomizer Burner.—The oil is brought through an orifice from which it is swept off by a brush of steam or air as in fig. 286. It is the principle made use of in the ordinary cologne spraying devices.

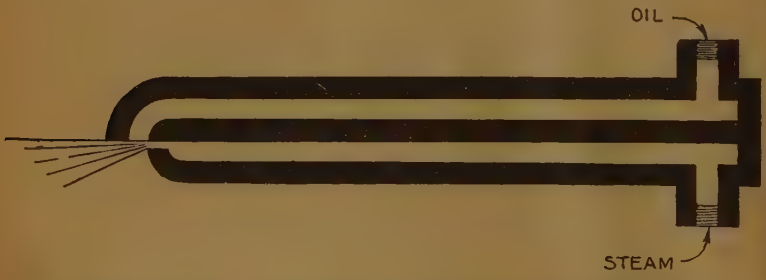


FIG. 286.—***Atomizer*** burner. The oil is brought through an orifice directly across the path of the jet of air or steam and is "brushed" off by the latter and sprayed.

Projector Burner.—The oil is pumped to the oil orifice and from there is caught by a passing gust of steam and is blown off as in fig. 287.

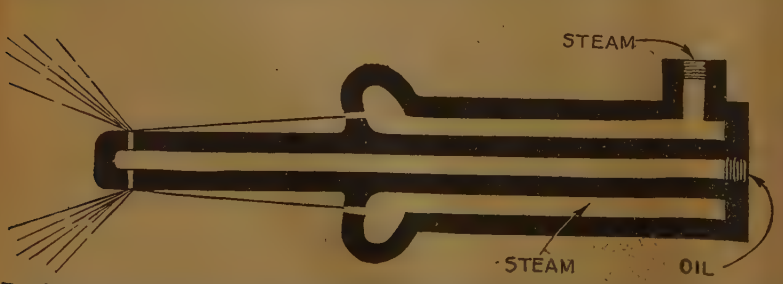


FIG. 287.—***Projector*** burner. The oil is pumped to the oil orifice and caught by the air or steam jets which are located some distance back of the oil orifice.

Outside Centrifugal Burner.—The oil is lead through the hollow spindle of a disc, which is rotated at high speed by a jet of steam acting on vanes attached to the circumference of the disc, and, overflowing onto the disc at its center, is hurled off the disc by centrifugal force and ignited by a torch, producing a ring of flame as in fig. 288.

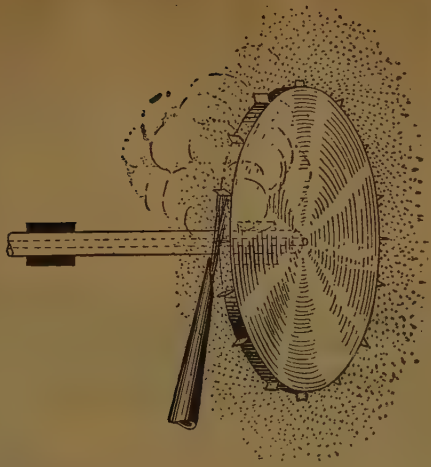


FIG. 288.—Outside centrifugal burner.

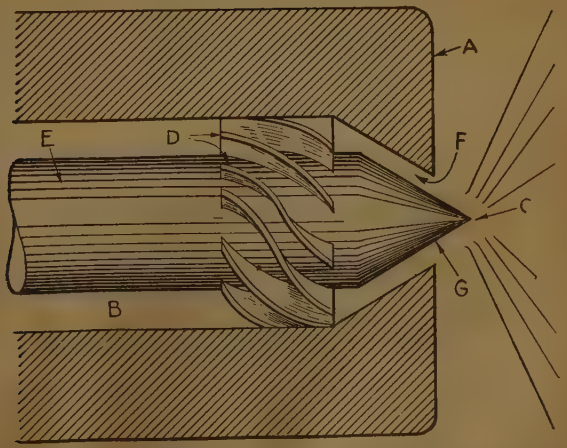


FIG. 289.—Inside centrifugal burner. ***In construction,*** at the end of the pipe A, that conveys the oil, the oil passage B, is tapered down to the opening C, through which the oil is discharged. The series of slanting vanes D, on the rod E, deflect the oil and break it up into a number of currents, each of which has a whirling motion as it enters the space F, around the end G, of the rod. The centrifugal force due to the whirling motion given by the vanes causes the spray to spread on leaving the burner as shown by the diverging lines.

These separate currents are intermingled at the orifice and on emerging spread out in diverging lines.

What is an inside mixing burner?

One in which the oil and atomizing agent meet inside the burner.

FIG. 290.—*Injector* inside mixing burner.

Inside Centrifugal Burner.—In the end of the pipe near the nozzle is placed a series of slanting vanes as shown in fig. 289, which deflect the oil and break it up into a number of currents, each of which has a whirling motion.

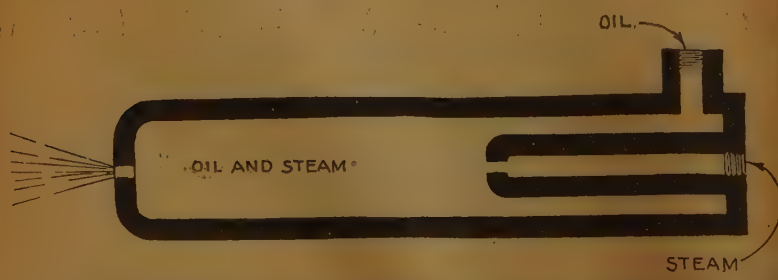


FIG. 291.—*Chamber* burner. The oil and steam are more or less mixed before issuing from the burner. With this burner the oil is heated before leaving the burner.

Injector Burner.—The principle here employed is similar to the injector used for boiler feeding. *In operation*, the steam and oil mingle within cone shaped passages and, as a mixture, pass through a contracted nozzle and then outward through a reversed flaring cone, as in fig. 290.

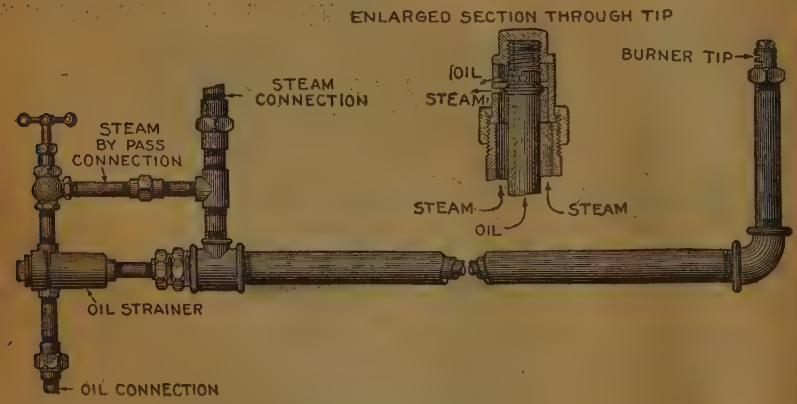
Chamber Burner.—The oil and steam are more or less mingled within the body of the burner as in fig. 291, and pass out from the tip or nozzle as a mixture, and then, owing to the expansion of the steam, the oil is rapidly broken into minute particles.

FIGS. 292 to 298.—Gem burners and parts. Fig. 292 regular Gem; fig. 293, improved Gem; figs. 294 to 298, *parts:* 1, tip; 2 tube; 3 nozzle; 4, body; 5, gap. In figs. 292 and 293, oil enters at one side of the burner and steam at the other; surrounding the inner oil tube heats the oil as it passes through. The jet formed at the outlet atomizes the oil. A whirling motion is given the steam by a whirl placed near the outlet. The improvement in fig. 293 consists of a needle valve which admits of a closer regulation of the oil supply. This burner is adapted especially for small boilers.

So Called Mechanical Burners.—These burners are properly termed centrifugal burners. In these burners the oil is given a whirling motion, preferably, within the burner tip. This is done either by forcing the oil through a passage of helical form or by delivering it tangentially to a circular chamber from which there is a central outlet. The oil is fed to these burners under a pressure which varies with the make of the burner and the rates at which individual burners are using oil.

The oil particles fly off from such a burner in straight lines in the form of a cone rather than in the form of a spiral spray, as might be supposed.

Where, in the spray burners, air is ordinarily admitted through a checkerwork under the burner proper, with the mechanical burner, it is almost universally admitted around the burner.



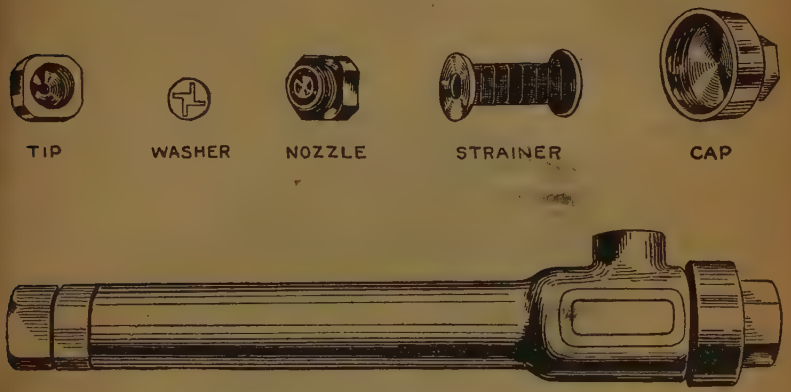
FIGS. 299 and 300.—Peabody burner and pipe connections.

Steam Consumption of Burners.—The Bureau of Steam Engineering, U. S. Navy, made in 1901 an exhaustive series of tests of various oil burners that may be considered as representing, in so far as the performance of the burners themselves is concerned, the practice of that time. These tests showed that a burner utilizing air as an atomizing agent, required for compressing the air from 1.06 to 7.45 per cent of the total steam generated, the average being 3.18 per cent. Four tests of steam atomizing burners showed a consumption of 3.98 to 5.77 per cent of the total steam, the average being 4.8 per cent.

Improvement in burner design has largely reduced the steam consumption, though to a greater degree in steam than in air atomizing burners. Recent

experiments show that a good steam atomizing burner will require approximately 2 per cent of the total steam generated by the boiler operated at or about its rated capacity. This figure will decrease as the capacity is increased and is so low as to be practically negligible, except in cases where the question of loss of feed water is all important.

There are no figures available as to the actual steam consumption of mechanical atomizing burners but apparently this is small if the requirement be understood to be entirely apart from the steam consumption of the apparatus producing the forced blast.



FIGS. 301 to 306.—Peabody burner and parts. Oil is delivered under pressure to an annular channel cut into the face of a nozzle upon which is screwed a tip having a very small central chamber communicating with a discharge orifice. Between the nozzle and the tip a thin washer or chamber disc is inserted and held firmly in place. This has a hole in the center corresponding with the diameter of the central chamber of the tip, and small slots or ducts, extending tangentially from the edges of the central opening outward toward the periphery of the washer, long enough to overlap the annular channel of the nozzle and put it in communication with the central chamber. The effect is that, when the burner is assembled with the washer in place, oil is delivered through the ducts tangentially to the central chamber where it rapidly revolves and almost immediately is discharged through the orifice in the tip. The burner is connected as shown in fig. 299.

Capacity of Burners.—As rated by manufacturers, burners may be obtained in sizes ranging from one, to over four hundred horse power. The question of capacity of individual burners is largely one of the proper relation between the number of burners used and the furnace volume.

In some recent tests with a Babcock & Wilcox boiler of 640 rated horse power, equipped with three burners, approximately 1,350 horse power was developed with an available draft of the .55 inches at the damper or 450 horse power per burner. Four burners were also tried in the same furnace but the

total steam generated did not exceed 1,350 horse power or in this instance 338 horse power per burner.

From the nature of mechanical atomizing burners, individual burners have not as large a capacity as the steam atomizing class. In some tests on a Babcock & Wilcox marine boiler, equipped with mechanical atomizing burners, the maximum horse power developed per burner was approximately 105. Here again the burner capacity is largely one of proper relation between furnace volume and number of burners.

Furnace Design.—Too much stress cannot be laid on the importance of furnace design for the use of this class of fuel. Provided a good type of burner be adopted, the furnace arrangement

FIG. 307.—Peabody and Irish impeller or air register. In a paper read before the Society of Naval Architects and Marine Engineers, Mr. Peabody says: "Great delicacy is required in introducing the air for combustion, very slight changes affecting the results in unsuspected ways, and while almost any method may result in smokeless combustion, maximum economy and capacity can be secured only by careful and intelligent design. It is not necessary to give the air a whirling motion but, judging from our rather exhaustive experiments, better gas analyses are secured, lower air pressures are required, and less refinement of adjustment is needed if the air be brought into contact with the oil spray with the right sort of a twist. We have found the impeller plate, illustrated on this page, most effective in accomplishing this mixture, and our most satisfactory results have been obtained with it."

and the method of introducing air for combustion into the furnace are the all important factors. No matter what type of burner be used, satisfactory results cannot be secured in a furnace not suited to the fuel.

What are the chief points to consider in furnace design?

The furnace should be of such shape, volume and arrangement that the combustion of the gases is completed in the body and that the gases are suitably retarded so that all possible heat is absorbed by the heating surface.

How should the burners be located?

They should be so placed that the products of combustion,

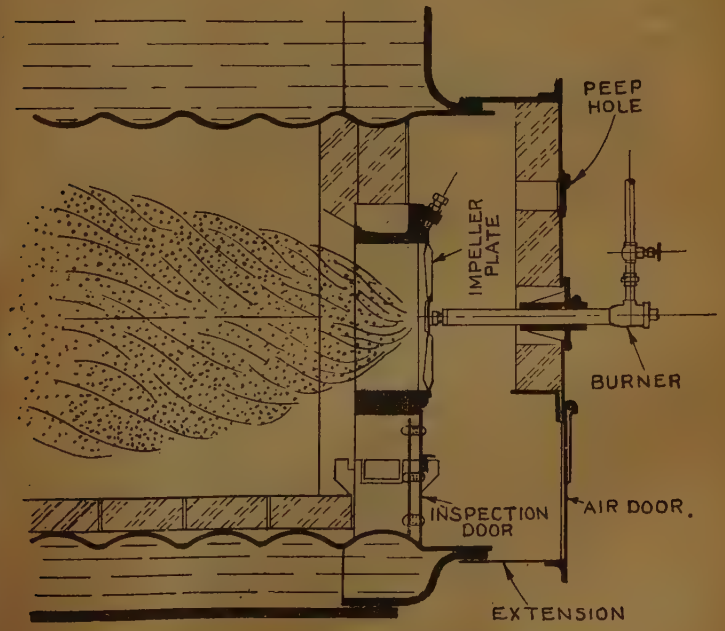


FIG. 308.—Peabody mechanical burner as applied to a Scotch marine boiler.

as they leave the oil, burning first, do not impinge on the cold tubes and metal of the boiler.

It is important to keep the side and bottom burners far enough from the side and bottom walls to prevent the formation of heavy masses of carbon by the oil spray, as these masses will eventually produce poorer combustion.

The flames from mechanical atomizing burners have a less velocity of projection than those from steam atomizing burners and if introduced into the higher end of the furnace, should not lead to tube difficulties provided they are properly located and operated. This class of burner also will give the most satisfactory results if introduced so that the flames travel in the direction of increase in furnace volume.

Operation of Burners.—When burners are not in use, or when they are being started up, care must be taken to prevent the oil

FIG. 309.—Monarch all brass burner. It is a combination burner for either "high or low" pressure, and is adjusted by the center lock nut working backward or forward. The feed pipes are regulated with standard valves and the oil adjusted by needle valve.

flowing and collecting on the floor of the furnace before it is ignited. In starting a burner, the atomized fuel may be ignited by a burning wad of oil soaked waste held before it on an iron

rod. To insure quick ignition, the steam supply should be cut down. But little practice is required to become an adept at lighting an oil fire. When ignition has taken place and the furnace brought to an even heat, the steam should be cut down to the minimum amount required for atomization. This amount can be determined from the appearance of the flame. If sufficient steam be not supplied, particles of burning oil will drop to the

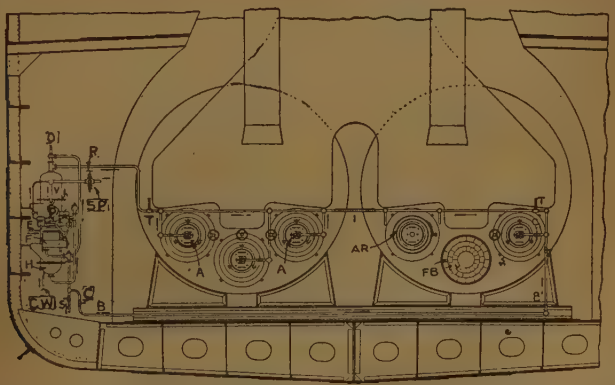


FIG. 310.—*Koerting* oil burning installation for Scotch boilers. The outfit comprizes: A, centrifugal oil sprayer; B, circulating line of heating; C, Cock; E, exhaust of pump; F, filter; H, oil heater; O, safety valve; P, steam pump; R, reducing valve; S, oil supply line; T, thermometer; V, air vessel; AR, air register; CW, condensed water; FB, fire brick; SP, steam pressure line. The full section of the furnace is used, the grate being unnecessary. Therefore there is a gain in heating surface. The heating and resulting expansion is equal, and all the water surrounding the tubes is correspondingly heated. The short fire clay lining in the furnace serves as a protection against the intense temperature of the oil flame, and enables the boiler to be readily set to work after a short interruption; the oil ignites on the incandescent fire-clay.

furnace floor, giving a scintillating appearance to the flame. The steam valves should be opened just sufficiently to overcome this scintillating action.

Air Supply.—From the nature of the fuel and the method of burning, the quantity of air for combustion may be minimized. As with other fuels, when the amount of air admitted is the minimum which will completely consume the oil, the results are the best. The excess or deficiency of air can be judged by the

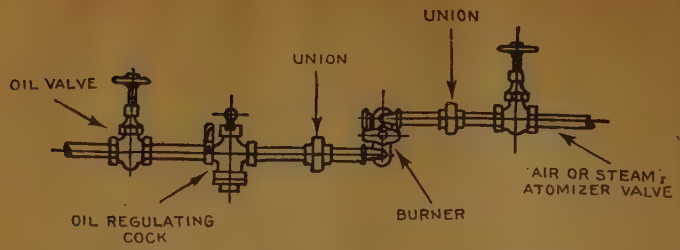


FIG. 311.—Correct method of connecting ***Best*** atomizer valve (air or steam), also regulating cock and oil cut out valve.

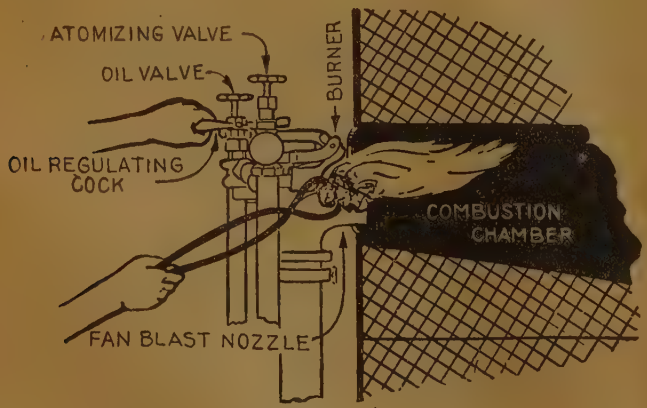


FIG. 312.—Correct method of starting ***Best*** oil burner. Open furnace door and keep it open until the brick work shows red. Saturate well a piece of cotton waste as large as a fist with kerosene, light it and hold with pair of tongs under nose of burner. Open atomizer valve slightly. As the flame from the burning waste draws into the combustion chamber, open full the globe valve on the oil line, then carefully turn on the oil by means of the oil regulating cock. Always be sure that there is flame from the burning waste entering the combustion chamber until the combustion chamber is above the igniting temperature of the fuel, after which the furnace can be heated to the required temperature by turning on more oil and air through the burner, also be feeding blast air through the blast nozzle above referred to. Be careful not to feed too much air or it will not only cool down the furnace, but will scale or oxidize the metal. Control oil supply so that no smoke is emitted from furnace. A clear heat should be kept in furnace, which is obtained either by cutting off a little oil or adding more air, preferably at blast nozzle, as blast air is cheaper than compressed air. After furnace is at required heat, no flame should appear at the doors or waste gas vents in the top furnace, save a green haze, which is simply the consumed gases passing away. Never allow any obstruction to stop up the vents in top of furnace. The deflection air blast simply keeps the heat from the operator, also helps to retain it in the furnace. Blast air from ½ oz. to ¾ oz. is sufficient. Dry steam or compressed air of from 15 lbs. up is used for atomizing the fuel. Oil pressure in all cases must be less than that of the atomizing agent. Tar or heavy oil should always be heated by means of a steam coil in the storage tank. Never regulate oil with a globe valve but with an oil regulating cock.

appearance of the stack or by observing the gases passing through the boiler settings.

What are the air supply indications?

A perfectly clear stack indicates excess air, whereas smoke indicates a deficiency.

How is the proper air supply best gauged?

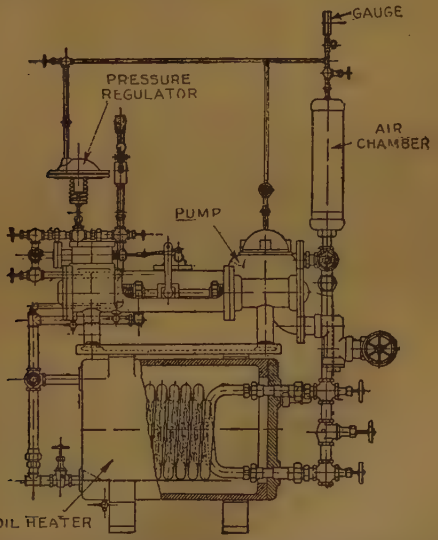


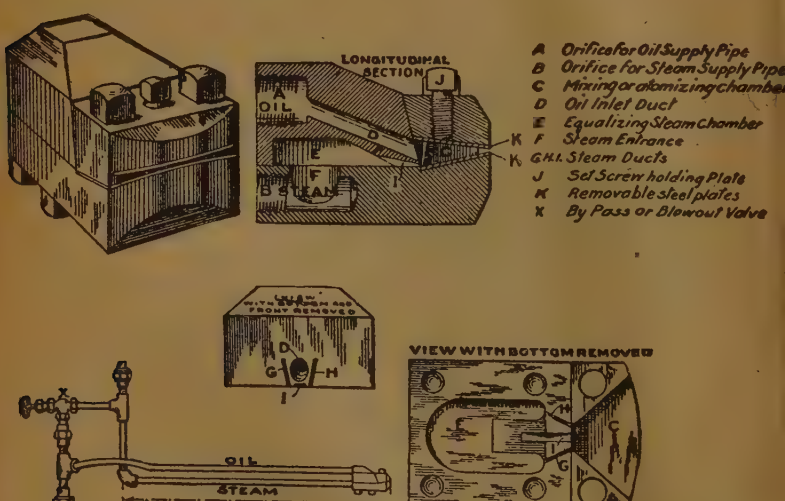
FIG. 313.—Lockett automatic fuel outfit. ***The heating*** is done by means of a brass coil through which the discharge from the pumps is led. The exhaust from the pumps being used to heat the oil. A live steam connection is also provided so that the oil may be heated to any desired temperature. To provide against danger in case the live steam connection is allowed to remain open when the pumps are not running, a safety valve is provided on the steam chamber. A closed oil relief valve is provided to prevent excessive oil pressure. The governor, air chamber and pump discharge chamber are provided with purge pipes to prevent any possible gas accumulation.

By running near the smoking point with a slight haze in the gases.

A slight variation in the air supply will affect the furnace conditions in an oil burning boiler more than the same variation where coal is used, and for this reason it is of the utmost importance that flue gas analysis be made frequently on oil burning boilers.

With the air for combustion properly regulated by adjustment of any checkerwork or any other device which may be used, and the dampers carefully set, the flue gas analysis should show, for good furnace conditions, between 13 and 14 per cent, of CO_2 with either no CO or but a trace.

In boiler plant operation it is difficult to regulate the steam supply to the burners and the damper position to meet sudden and repeated variations in the load. A device has been patented which automatically regulates by means of the boiler pressure the pressure of the steam to the burners, the oil to the burners and the position of the boiler damper. Such a device has been shown to give good results in plant operation where hand regulation is difficult at best, and in many instances is unfortunately not even attempted.



FIGS. 314 to 318.—***Hammel*** inside mixing oil burner. ***In operation,*** oil enters at A, flow through D, into the mixing and atomizing chamber C; steam enters at B, passes through E, and then through three small slots, G, H, and I, into mixing chamber C, where it mee the oil, and as these small steam jets cut across the oil stream at an angle, the energy of t steam is fully utilized and the burner requires only about 2 per cent or less of the amount steam generated by the boiler, the heavy hydrocarbons are completely atomized, the lig hydrocarbons are vaporized, and the completed mixture issues from the burner and ignit like a gas flame.

Efficiency with Oil.—As pointed out in enumerating the ad vantages of oil fuel over coal, higher efficiencies are obtainab with the former. With boilers of approximately 500 horse pow

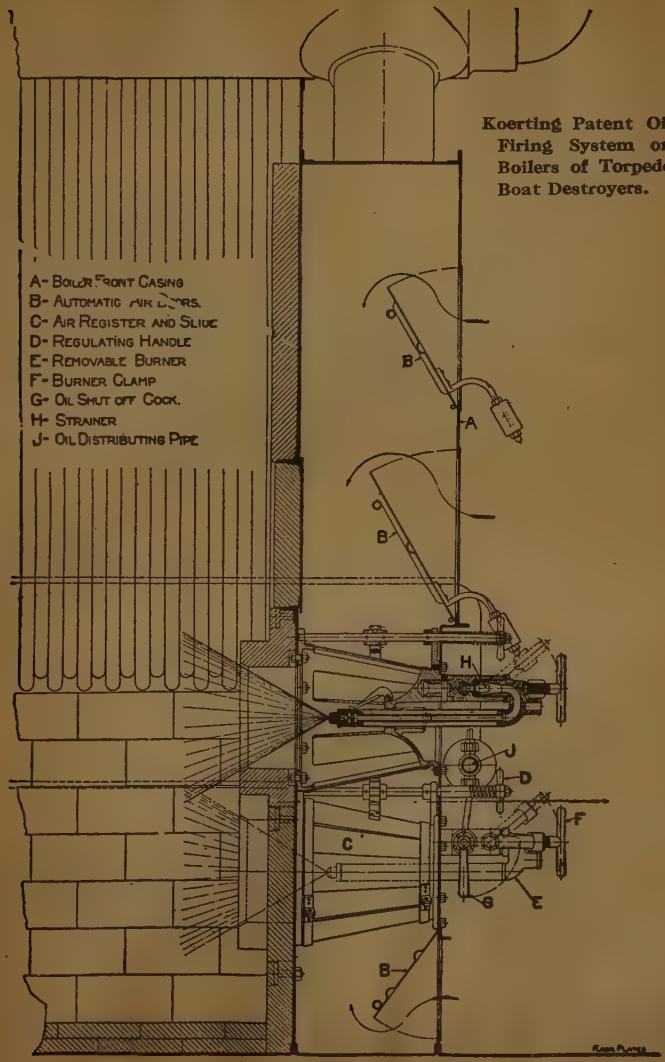


FIG. 319.—Schutte and Koerting oil burning system as applied to boilers of torpedo boat destroyers.

equipped with properly designed furnaces and burners, an ef-
ficiency of 83 per cent is possible or making an allowance of 2
per cent for steam used by burners, a net efficiency of 81 per cent.
The conditions under which such efficiencies are to be secured are
distinctly test conditions in which careful operation is a prime
requisite.

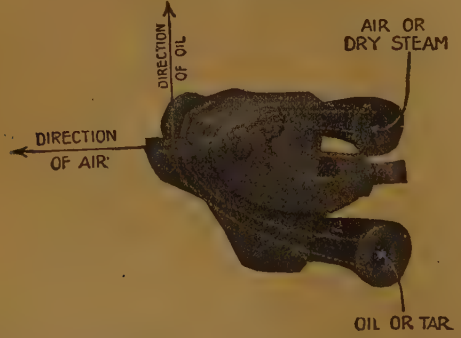


FIG. 320.—***Best*** high pressure type burner, for light or heavy oil, or tar. ***In operation,*** the air or steam meets the oil at right angles. By releasing the set screw in yoke and raising the lips, any obstruction that might find its way through the air line can be blown out.

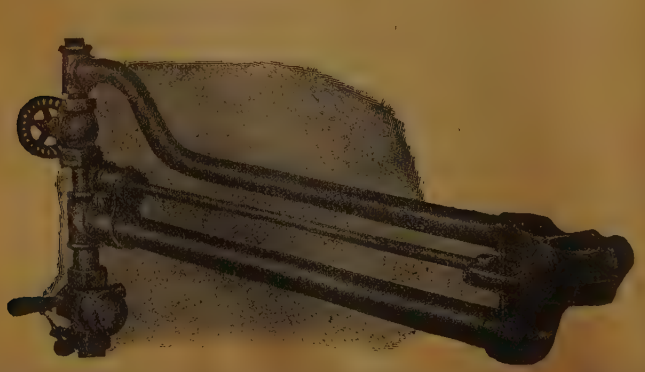


FIG. 321.—***Best*** burner mounted for boiler. The burner is connected to piping of sufficient length to go through the front setting of boiler. By means of the by pass valve any foreign substances that may enter the oil pipes can be blown out. The atomizer lip is hinged and held tight against the body of the burner, but means are provided for raising the lip to blow out the atomizer pipe in case any foreign substance such as scale, red lead, etc., should lodge therein. This can be accomplished without removing the burner from boiler.

ATOMIZER.

FIRE BOX SHOWING DEFLECTING PLATES

FIGS. 322 to 325.—Racine oil burning system for small vertical boilers up to 20 horse power. Fig. 322 burner; fig. 323, oil trap; figs. 324 and 325 fire box disassembled showing deflecting plates, and assembled. In fig. 324 when the oil level is reached the supply is cut off by the float rising and closing the oil level. The outlet to the burner being above the oil level, and the oil supplied to the burner by the vacuum created there can be no overflow.

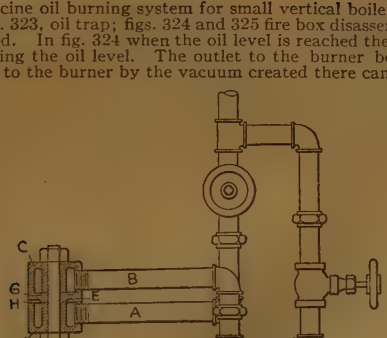
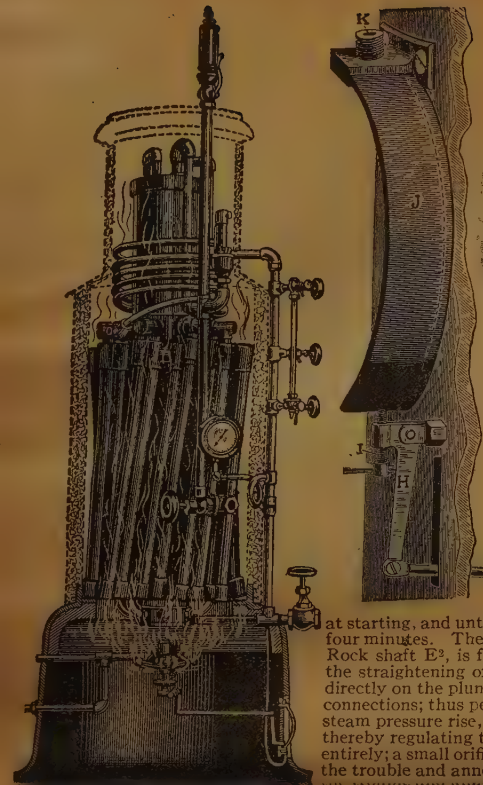
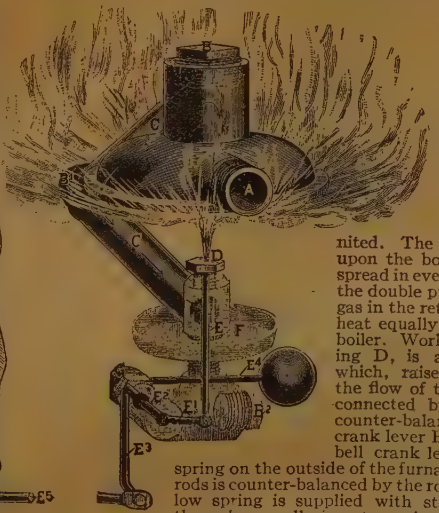


FIG. 326.—Slot oil burner with renewable disc. The steam pipe A, and oil pipe B, are made of such length as to bring the tip of the burner to the proper point in the furnace. The burner consists of two cup shaped castings C and D, separated by a narrow disc E. The three pieces are of the same diameter and are held together firmly by the central bolt F. As shown in the separate views, the disc E, has its rim cut away on both sides for about one-third of its circumference. Thus, when it is bolted between the castings C and D, two slots G and H, are formed, extending about one-third of the way around the burner. The oil flows through the upper casting C, and drools over the edge of the disc E, from the slot G. The steam flows through the lower casting D, and escapes through the slot H, meeting the oil and spraying it so as to produce a wide fan shaped flame. The greater part of the wear due to erosion comes on the disc E, which can be renewed when badly worn. The arrangement of the regulating valves for oil and steam and of the by pass for cleaning is similar to that already described.

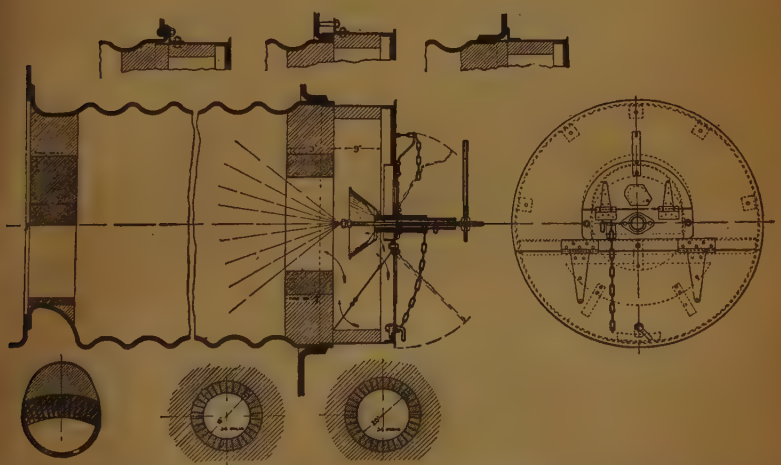




FIGS. 327 and 328.—***Vaporizing*** or ***gas*** type burner and method of installing in small marine boiler. It is designed for naphtha, benzine, gasoline or other light hydrocarbons or ordinary headlight oil, of 150° test. ***In operation,*** the oil is supplied through a pipe to the vaporizing retort indicated by the letter A. In its passage through the fire box and this retort it is converted into a vapor or gas, which burns without odor, soot or residuum. From the top of the retort A, the gas is conveyed through an elbow pipe C (as shown by arrows) to the mouth of the burner, where it escapes through a small opening D (made adjustable) and is ignited. The flame striking centrally upon the bottom of the retort A, is spread in every direction, thus serving the double purpose of generating the gas in the retort and distributing the heat equally to every portion of the boiler. Working into this small opening D, is a shut off plunger, E, which, raised or lowered, controls the flow of the gas. This plunger is connected by means of a rod E^1, counter-balanced rock shaft E^2, bell crank lever E^3, connecting rod E^5, to bell crank lever H, and to a hollow spring on the outside of the furnace. The weight of these rods is counter-balanced by the rod and ball I^4. The hollow spring is supplied with steam at boiler pressure through a small pipe at opening K. The saucer F, is for oil or alcohol used in raising the proper heat under retort at starting, and until sufficient gas is manufactured for its own reproduction; a matter of three or four minutes. The burner is furnished with removable plugs BB^1, and B^2, to facilitate cleaning. Rock shaft E^2, is furnished with stuffing box G, to prevent leakage. It will readily be seen that the straightening of the spring, caused by an increase of pressure in the generator, operates directly on the plunger by means of the adjusting screw I, bell crank lever H, and intermediate connections; thus perfectly establishing the relation between steam pressure and fire. Should the steam pressure rise, the plunger would close off the flow of gas correspondingly, and vice-versa, thereby regulating the heat of the fire. The plunger cannot, however, shut off the flow of gas entirely; a small orifice is always left, enough to keep the burner and generator hot; and in this way, the trouble and annoyance from having to relight the fire after every stop is avoided.

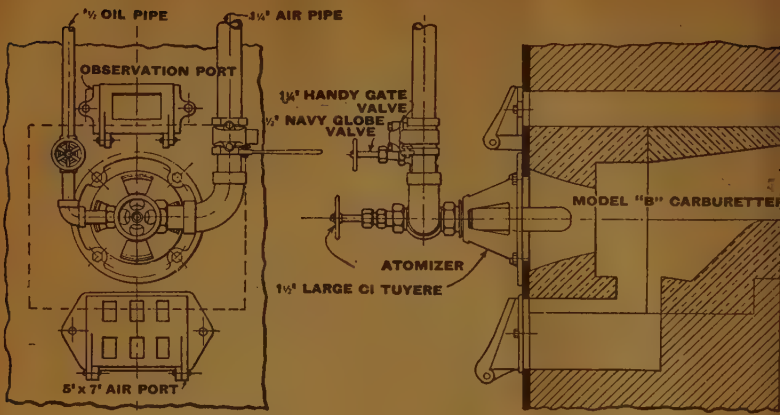
With furnace conditions that are not conducive to the best combustion, this figure may be decreased by from 5 to 10 per cent.

In large properly designed plants, however, the first named efficiency may be approached for uniform running conditions, the nearness to which it is reached depending on the intelligence of the operating crew.



FIGS. 329 to 336.—Furnace front for Dahl mechanical oil burning system. This system has been adopted by many of the Pacific coast steamship companies, and was the first mechanical system to successfully operate with the heavy California oils. The burner is simple, having only a few parts, consisting of a tip, atomizer, strainer, tube and valve. ***The operation*** of the burner is regulated by the pressure of the oil line, rather than the valve of the burner. The furnace front as shown is so arranged that the burner passed through a pipe on the end of which is a cone or deflector which can be adjusted by moving it in or out to insure the proper quantity of air just when it is needed. The front is extended so that the whole length of the furnace is utilized and the brickwork is so fitted that repairs and examination can be made without removing it.

It must be remembered that the use of oil fuel presents to the careless operator possibilities for wastefulness much greater than in plants where coal is fired, and it therefore pays to go carefully into this feature.



FIGS. 337 and 338.—Typical setting of Billow, class DM, atomizer in connection with model G1 carburetter. The observation port above the tuyere block enables the operator to examine the condition of the fire through a mica window without exposure to the heat or glare of the flame. The air port below the carburetter permits controlling the air supply to furnace and tuyere block and the tuyere controls the amount of air entering around the atomizer.

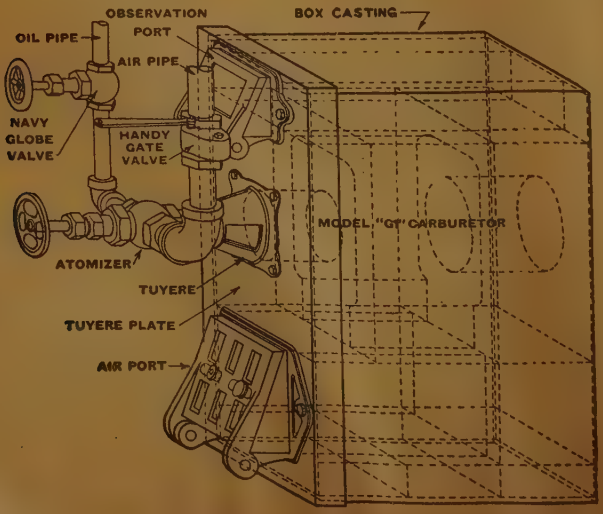
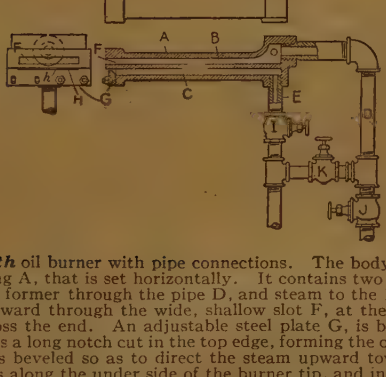


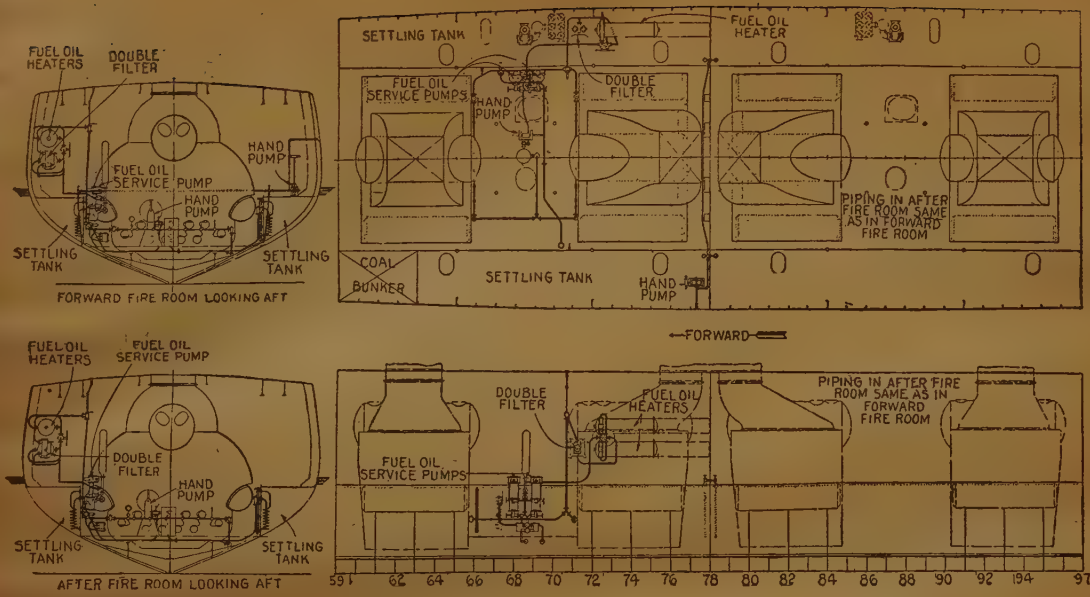
FIG. 339.—Typical mounting of Billow atomizer model G1 carburetter.

Water-gas Tar.—Water-gas tar, or gas house tar, is a by-product of the coal used in the manufacture of water gas. It is slightly heavier than crude oil and has a comparatively low flash point. In burning, it should be heated only to a temperature which makes it sufficiently fluid, and any furnace suitable for crude oil is in general suitable for water-gas tar. Care should be taken where this fuel is used to install a suitable apparatus for straining it before it is fed to the burner.

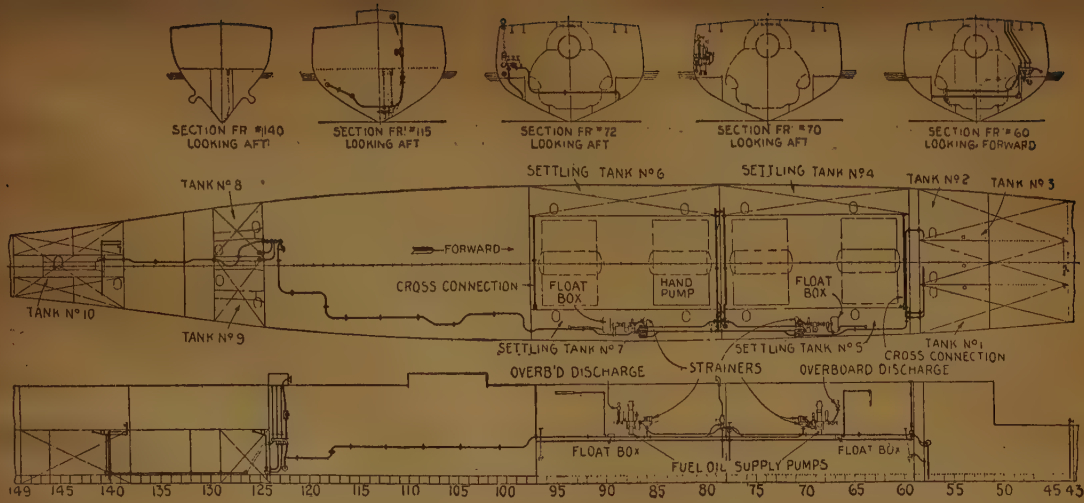


FIGS. 340 to 342.—***Booth*** oil burner with pipe connections. The body of the burner consists of a box-shaped casting A, that is set horizontally. It contains two passages, B and C, oil being admitted to the former through the pipe D, and steam to the latter through the pipe E. The oil flows outward through the wide, shallow slot F, at the tip of the burner and drools downward across the end. An adjustable steel plate G, is bolted across the steam orifice. This plate has a long notch cut in the top edge, forming the outlet H, for the steam, and on the inside it is beveled so as to direct the steam upward toward the orifice. The escaping steam sweeps along the under side of the burner tip, and in expanding, sprays the oil that runs down from the upper slot. The bolts that hold the plate G, in place, pass through long vertical slots in the plate, and this construction allows the plate to be moved up or down to give the desired depth of slot H. This adjustment, of course, is made when the burner is disconnected and not in use. The arrangement of the piping is simple. The supply of steam is brought to the burner through the pipe E, the flow being regulated by the valve I. In the same way a valve J, in the oil line D, is used to control the rate of flow of the oil. Between the oil pipe and the steam pipe is inserted a short connection fitted with a valve K. This serves as a by pass to admit steam to the oil passage when it becomes necessary to clean out the passage. The oil valve J, and the steam valve I, are first closed and then the by pass valve K, is opened. The steam rushes through the oil passage, and its heat and its cutting action together scour the passage clean. The steam passage may be cleaned by removing the plate G, completely, and allowing steam to blow through at full pressure. The passages in the burner are straight and fairly large to avoid frequent clogging.

It would appear from experiments that such a combination gives satisfactory results from the standpoint of both capacity and efficiency, if the two fuels are burned in separate furnaces. Satisfactory results cannot ordinarily be obtained when it is attempted to burn oil fuel in the same furnace as the primary fuel, as it is practically impossible to admit the proper amount of air for combustion for each of the two fuels simultaneously.



FIGS. 343 to 353.—Diagram showing arrangement of oil piping of ***U. S. S. Patterson.*** As described by the Bureau of Steam Engineering: "The system comprises storage tanks forward and aft, and two settling tanks in each fire room, abreast of the boilers, together with the necessary pumps, oil heaters, strainers, etc. In each fire room there are one light service supply pump, two duplex pressure pumps and two oil heaters, each of sufficient size to heat all the oil used in same compartment to the desired temperature. For raising steam with no source of power available, a hand pump is provided in each fire room, of suitable size to supply oil at necessary pressure to two burners. From the bottom of each forward storage tank a pipe is led to the suction and filling manifold in the forward fire room. A similar manifold is provided in the engine room connected to pipes from the after group of storage tanks. From each manifold a combined suction and discharge pipe is led to the combined suction and discharge manifold at each supply pump. There are Macomb strainers in both suction and discharge connections between the [illegible]



FIGS. 343 to 353.—*Text continued.*

normally draw from the storage tanks and discharge into the settling tanks, which are cross-connected in each fire room for maintaining the same oil level in both tanks. In order to prevent overflowing the settling tanks, the starboard tank in each fire room is fitted with a float, which actuates a chronometer valve in the steam line to the supply pump, automatically shutting it down when the oil in the tank has reached a predetermined height. The supply pumps are also arranged for transferring oil from the forward to the after storage tanks and vice versa. They are also fitted to draw from the settling tanks and to discharge overboard when cleaning tanks. These pumps can also discharge oil to another vessel in emergency, via the deck filling connections. All tanks are filled from the deck via supply pumps, combined suction and discharge pipes. Extending from just below the mid-depth of each settling tank, with end surrounded by a steam coil, a suction pipe is led to the service pumps, in same compartment and fitted with strainers, at pumps. The service pumps discharge through strainers and heaters, the latter arranged with by pass to the oil burners. Large air chambers are provided on the pumps' discharge. The cut out valves to the burner lines, across boiler fronts, are fitted for emergency operation from the deck above. A hand pump is also provided in the after fire room for freeing the settling tanks of water and discharging same overboard."

Burning Oil in Connection with Other Fuels.—Considerabl attention has been recently given to the burning of oil in con nection with other fuels, and a combination of this sort may b

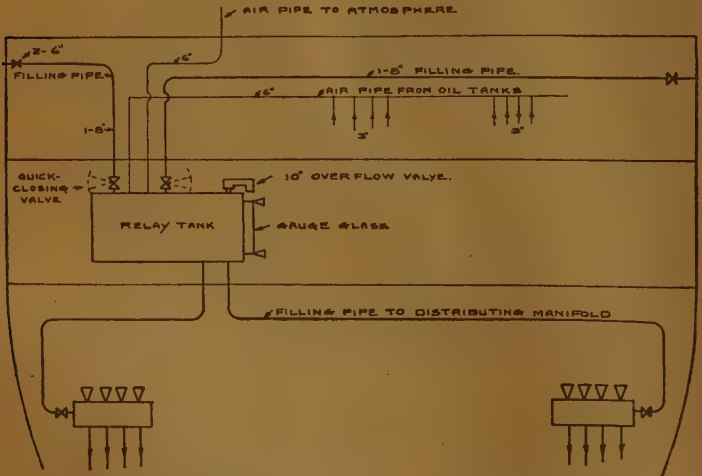


FIG. 354.—Diagram of filling pipes and relay tanks U. S. S. Pennsylvania. Two 6-in. pip with valves are located on each side of the ship, connecting with one 8-in. filling pipe on eac side, which runs to the relay tank. The latter is fitted with a removable cover and a larg (10-in.) overflow closed by a relief valve with a very light spring. Filling pipes lead fro the relay tank to the storage tanks, and it is evident that the greatest pressure which ca be put on the latter is that due to the head from the relay tank, which can be reduced to smaller amount by suitably locating such tank. The vent pipes from the storage tanks lea into the relay tank, which is fitted with a common vent pipe leading to the atmosphe and covered at the end with wire gauze. The supply pipes to the relay tanks are fitted wit quick closing valves and the relay tank is equipped with a gauge glass to mark the level the oil. Also an annunciator at the relay tank, operating from the "pneumercators" fitte in the storage tanks, gives warning when the latter are 95% full. On the relay tank whic is used only in filling and not for permanent storage, the fitting of a gauge glass is no doub justified, but the use of fittings of any kind on the outside of the tanks below the oil level in general very bad practice, and should be avoided where possible. Floating suctions, storage tanks, for taking the oil from a point near the surface are no longer considere necessary, the usual practice being to use a high and low suction, *i. e.*, two pipes eith separate or connected through a manifold, one taking the oil from a level 12 to 18 inch from the bottom of the tank and the other from a point within a few inches of it—n more than four inches. The upper suction is used for regular service, and at all tim except in emergency—or when the supply is very low or when the low suction is employe to pump overboard water or very dirty oil which has accumulated at the very bottom the tank.

advisable either with the view to increasing the boiler capacit to assist for heavy demands, or to keep the boiler in operatio

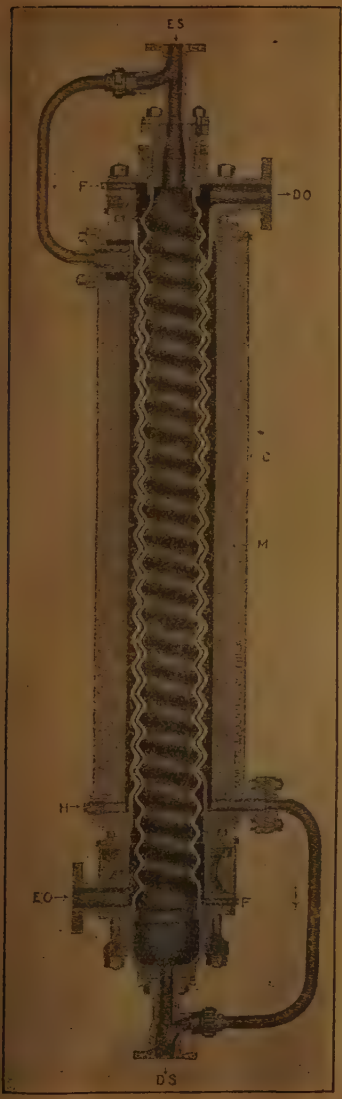


FIG. 355.—*Schutte and Koerting* film oil heater. In this heater (invented by Lovekin) oil is forced in a thin film between two steam heated surfaces of such shape that the oil is continually being mixed or stirred in passing through the heater.

where there is the possibility of a temporary failure of the primary fuel.

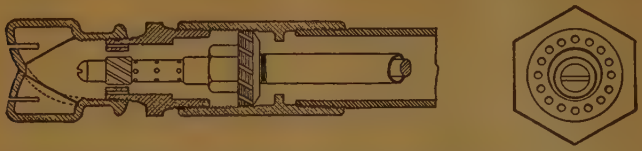
Conversion of vessels for use with coal or oil.—While the U. S. Navy has definitely adopted oil fuel for all classes of service and the later vessels are constructed without provision for coal bunkers, it may appear of advantage to the mercantile vessel owner to be ready to use either fuel. This can be easily accomplished if means are provided for carrying coal fuel.

The change of the boilers consists merely of removal of the burners and oil piping, air controling mechanism and special brickwork that may have been used, and substitution of a few necessaries, such as grate bars and fire doors.

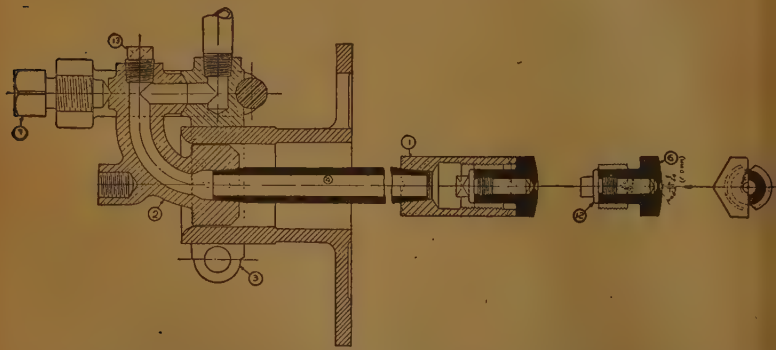
Where steam atomizing burners are used, the grate bars and bearers are usually retained while burning oil, and merely covered with a protecting layer of fire brick.

The changes in the bunkers also are simple, if proper precautions ar taken beforehand.

Mr. George Simpson, the well known naval architect, gives the follow ing rules for arranging the bunkers for alternate use with either fuel:



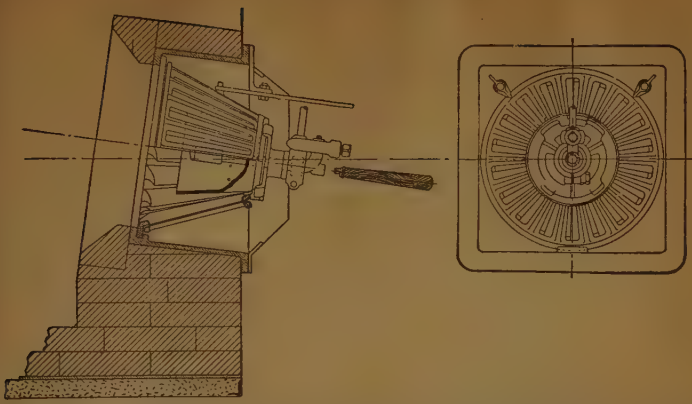
FIGS. 356 and 357.—***Staples and Pfeiffer*** flat flame inside mixing atomizer; a type exten sively used for marine work on the Pacific coast.



FIGS. 358 to 360.—***Bailey burner.*** ***In construction*** a quick detachable coupling fastene with a yoke is used to hold the burner in position and a wooden handle may be screwed int the burner elbow to facilitate handling. A steel tube is screwed into the coupling castin and on the other end of the tube is screwed a composition nozzle which is adapted to r ceive a steel tip provided with a central chamber 3/8-in. in diameter. A special plug adjustable length is screwed into the end of the chamber, so that the actual volume of th chamber in which the oil is given its rotary motion is adjustable. Grooves in the threade portion of the tip are provided for delivering the oil under pressure to an annular space ju outside the central chamber. Oil passes to the central chamber through two small ope ings or round channels drilled in the tip at an angle of about 45° to a plane at right angl to the axis of the burner. These channels are tangential to the sides of the central cha ber, so that as the oil enters the chamber it acquires a rapid whirling motion and issu from the orifice in the tip in a finely divided conical spray.

Specification for Coal or Fuel Oil Bunker

General Description.—"The cross bunker to be arranged adjacent to the fire room and consist of two thwartship oil tight bulkheads of a predetermined capacity. There shall be center line oil tight bulkhead dividing the cross bunker into port and starboard compartmen and in addition there shall be partial swash bulkheads extending throughout the upper h of the bunker."



FIGS. 361 and 362.—***Bailey air control*** as fitted to the Babcock and Wilcox boilers on the S. S. Malsonia. It consists of a cast iron grid of the shape of a truncated cone, the walls of which are cored so as to provide channels for the admission of the air. The passages are curved to give the air a rotary motion. Outside this grid there is a cover which may be revolved by means of a lever; this cover is slotted to correspond with the air passages in the truncated cone, and thus serves as a means for regulating the quantity of the entering air or for closing it off entirely. Inside the cast iron grid there is another truncated cone of different dimensions designed to protect the tip of the burner from direct impact of the air; this is shown partly in section in the drawing. The burner is installed through the small end of the truncated cone, and in this particular design the burner is inclined slightly upward from the horizontal line in order to give an upward sweep to the spray as it enters the furnace. The design is adapted to operate natural draft, but not forced draft.

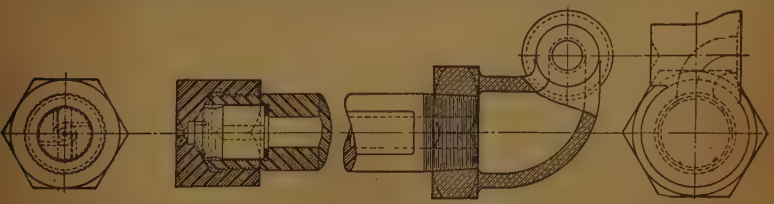
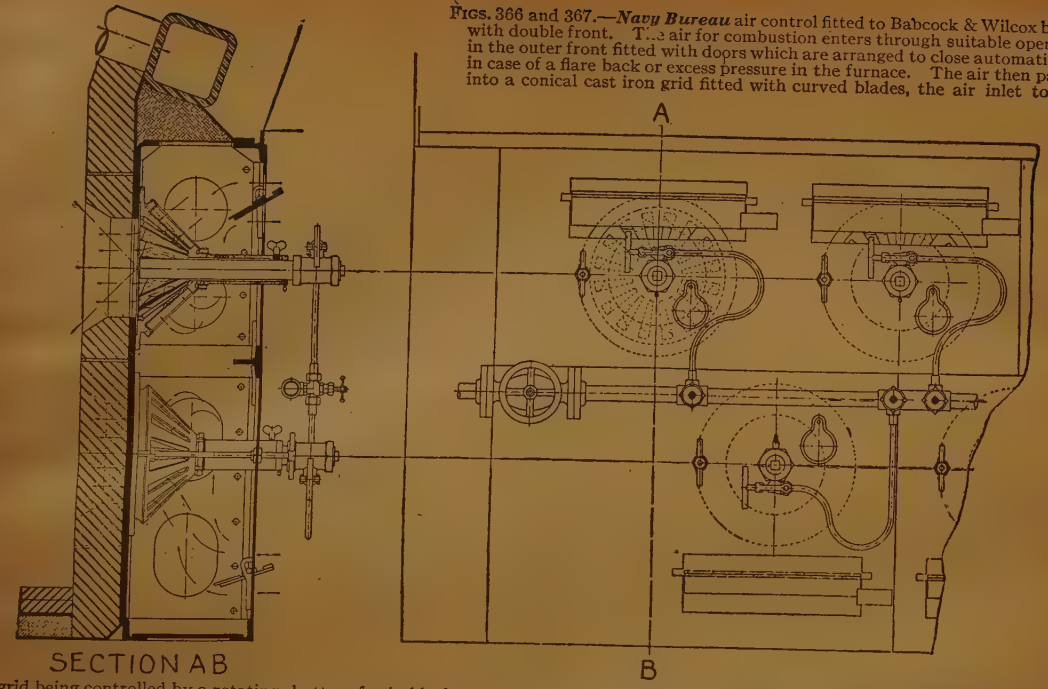


FIG. 363 to 365.—***Navy Bureau*** standard burner (designed by Lieut. Starr). The oil passes directly into a heavy steel tube, the end of which is recessed to receive a steel plug which is chamfered, on the end which faces the tip of the burner, at an angle of about 26° with a plane at right angles to the axis of the burner. The extreme end of the plug is faced off smooth to give a flat surface which corresponds in diameter with a recess in the steel tip, which in turn communicates with the outlet orifice through a small conical chamber. On the conical face of the plug four grooves are cut which are tangential to the chamber in the tip. The oil reaches the outer ends of these tangential channels by passing through a hole drilled in the center of the plug which communicates with another hole drilled at right angles to same, thus delivering the oil to an annular chamber formed by a recess machined in the side of the plug. The steel tip itself screws on to the end of the oil pipe in such a way as to provide a large chamber to receive the plug, which latter was originally intended to be movable in the direction of the axis of the burner, the idea being that this "floating" plug would be held tightly against the tip ordinarily by the pressure of the oil, but in case of dirt getting into one of the tangential channels, the pressure would force it through by driving the plug back slightly from its seat on the tip. In practice it has been found necessary, however, to use a small lead gasket to hold the plug firmly against the tip, as the oil pressure could not always be depended upon to do this.

FIGS. 366 and 367.—***Navy Bureau*** air control fitted to Babcock & Wilcox boiler with double front. The air for combustion enters through suitable openings in the outer front fitted with doors which are arranged to close automatically in case of a flare back or excess pressure in the furnace. The air then passes into a conical cast iron grid fitted with curved blades, the air inlet to the



grid being controlled by a rotating shutter of suitable form on the exterior of the same. This is operated by means of a small gear wheel connected with a shaft which extends through the outer front and is provided with a handle, as shown in the drawing. The burner is installed through a sleeve which connects with the grid casting or may be made an integral part of same. It will be noted that the burner tip extends well into the interior of the cone and no protecting device around the tip is used. The Navy Department has granted permission to the ship builders or other interested parties for the free and unrestricted use of the Bureau design of burner and air control, and it is being fitted in many installations.

"The hatchway shall consist of a coaming 24" in height plated over the top and arranged with two oil hatches.

Oil tight Bulkheads.—"The oil tight bulkheads must be suitably stiffened with vertical stiffeners and webs, as well as horizontal girders, the scantlings and arrangement being as required by Lloyd's Rules for oil tight work. The center line bulkhead should extend from inner bottom to coaling hatch with plating and stiffeners to Lloyd's requirements.

Hatchway.—"A steel cover on top of the 24" coaming forming the hatchway shall be arranged with hinges and drop bolts to enable the whole of cover to be readily opened up for coaling purposes, and when carrying oil this cover will be arranged with a lamp wick gasket and the cover screwed down and made oil tight. In addition there shall be two small oil hatches

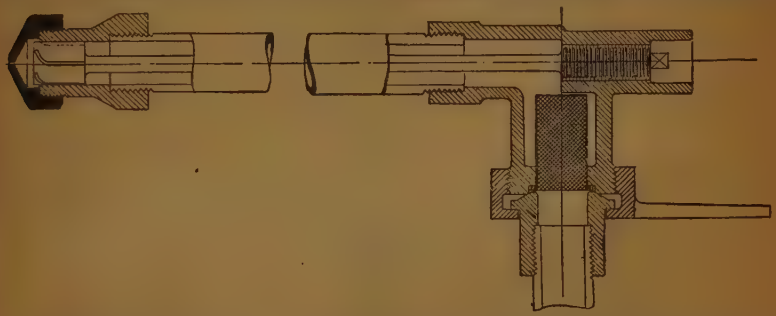
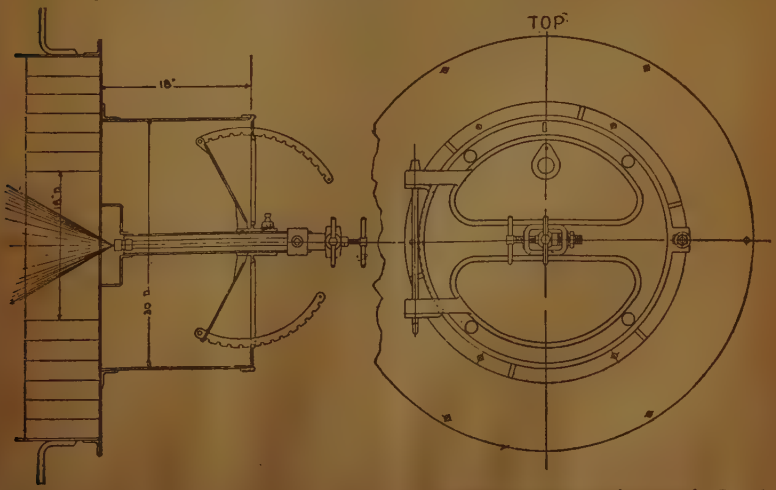


FIG. 368.—***Moore & Scott*** burner. The oil is delivered to the chamber communicating with the discharge orifice, through oil passages cut in the sides and on the end of a plug which is adjustable in the direction of the axis by means of a spindle passing completely through the burner; a special strainer is used and the union for connecting the oil piping is fitted with a special means for detaching quickly.



FIGS. 369 and 370.—***Moore & Scott*** air control as arranged for use in the furnace of a Scotch boiler.

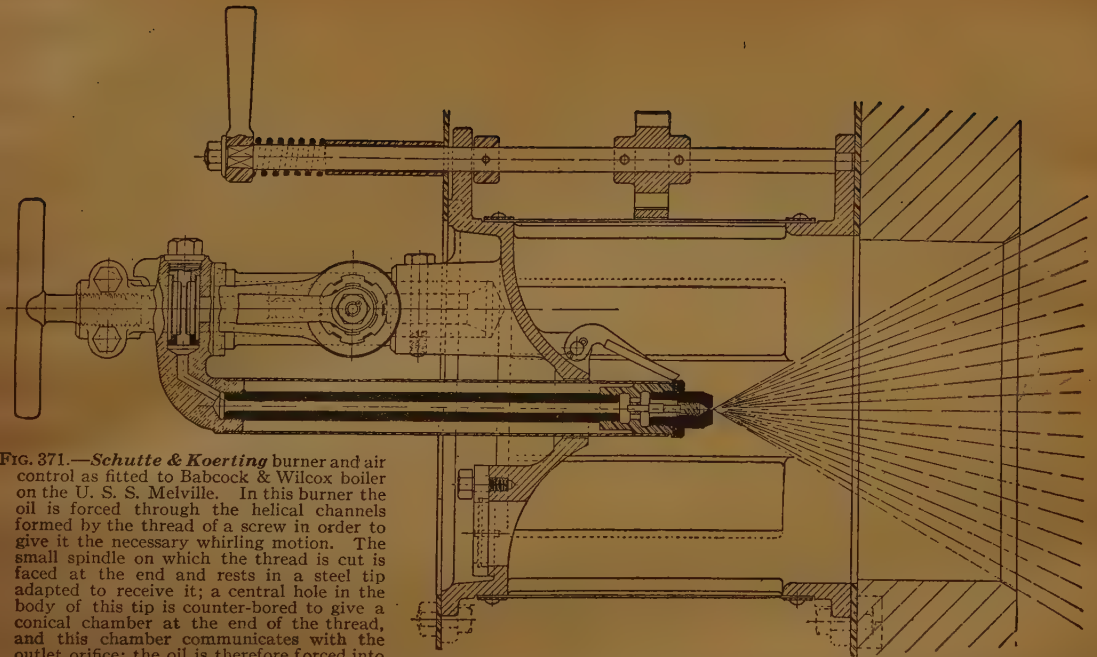


FIG. 371.—***Schutte & Koerting*** burner and air control as fitted to Babcock & Wilcox boiler on the U. S. S. Melville. In this burner the oil is forced through the helical channels formed by the thread of a screw in order to give it the necessary whirling motion. The small spindle on which the thread is cut is faced at the end and rests in a steel tip adapted to receive it; a central hole in the body of this tip is counter-bored to give a conical chamber at the end of the thread, and this chamber communicates with the outlet orifice; the oil is therefore forced into the small conical chamber with the rotary motion due to the action of the thread. The end of the spindle opposite the helical thread is squared in section and fits into a square hole in the nozzle of the burner, which prevents the spindle rotating when in operation. The air admission chamber is cylindrical in shape and is provided with longitudinal openings parallel with the axis of the burner, which admit the air for combustion. These openings are covered by an adjustable sheet iron cylinder, which fits on the outside, and the air is controlled by rotating this cover. The air is not given a whirling motion. In order to obtain the best mixtures and prevent pulsations, a high air pressure is usually carried and the air forced through restricted openings at high velocity.

on the main hatchway cover arranged so as to be readily opened and fitted with peep holes and ventilators.

Coal Doors.—"The stokehold bulkhead to be arranged with coal doors of the usual dimensions, the frames of which shall be secured with bolts and nuts so as to be readily removable when changing over to oil, and a steel plate cover substituted and set up on a lamp wick gasket, or alternatively, the plate may be riveted in place and caulked.

Fuel Oil System.—"The fuel oil system shall consist of a high and a low suction in each tank led to Warren or other suitable oil fuel pumps with the usual arrangement of heaters, duplex strainers, meters and thermometers, the whole system being cross connected and interchangeable so that the break down of one pump need not put that particular unit of the system out of commission, but can be connected up with the other pump and these pumps so cross connected that each can handle its own or opposite system.

Finally.—"Generally there is no practical difficulty in arranging a cross bunker for the

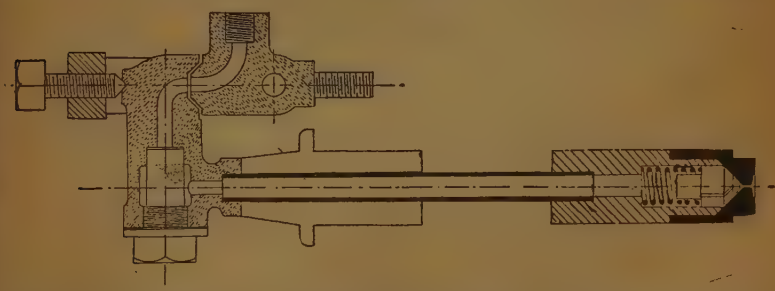


FIG. 372.—***White burner;*** extensively used in merchant vessels on the Atlantic coast. The mechanism for giving the oil a whirling motion consists of a plug which seats against the inner surface of the tip and is held in position by a spring. Oil passes along the grooves cut in the cylindrical portion of the plug and then along the corresponding grooves cut in the conical end, which are so arranged as to deliver the oil tangentially to the central chamber in the tip and at an angle of about 45° to a plane at right angles to the axis.

NOTE.—***Corrosion due to oil.*** Certain grades of the heavier oils contain considerable sulphur and the question is frequently asked whether or not corrosion from this cause may result. At the opening of the Beaumont fields, particularly, there were many, who on general principle, prophesied rapid deterioration of boiler surfaces, without giving due thought to the fact that certain kinds of coal having a larger sulphur content than the oil had for years been used for fuel without serious trouble. Experience has demonstrated that sulphur in oil has no bad effect on boilers, except in cases of neglect, when pitting may occur under certain conditions, the same as with coal. Corrosion of copper heating coils has, however, been noticed in the presence of sulphur bearing oils, and for this reason it is the recognized practice to use steel coils. Brass and bronze fittings may be used, however, with safety, both in pumps and on pipe lines, and doubtless brass heater tubes could be employed if desired.

NOTE.—***Oil piping for U. S. Naval Service.*** The piping specified is seamless drawn steel, with flanges expanded on. The joints are scraped and made up metal to metal. Manila paper gaskets are allowed on suction piping. Screwed fittings are used on connections under ¾-in. For merchant service extra heavy welded iron or steel pipe is used, with screwed joints and with extra heavy galvanized iron fittings. Flanges are screwed on the pipe and manila paper or card board is used for gaskets, or special oil proof packing, of which there are several kinds in the market. Rubber is not allowable on account of sulphur in the oil. Copper piping is not used on account of the sulphur, but brass and composition fittings, valves, unions, etc., may be used safely. The suction piping should be large, the Newport News rule for designed velocity of Mexican oil through suction pipes being not over twenty feet per minute, the oil being heated to reduce the viscosity to about 300° Engler. For discharge pipe lines they consider 100 feet per minute allowable in small pipes, the viscosity being reduced to 15° Engler or under.

stowage of either coal or fuel oil provided the hatchway is made large enough and arranged with a steel cover. Care should be observed in arranging the wing swash plates that they shall only extend for the upper part, thus permitting the coal to gravitate freely to the bunker doors.

"With a system such as has been outlined in the foregoing, a change over from one fuel to the other can be made in a few hours."

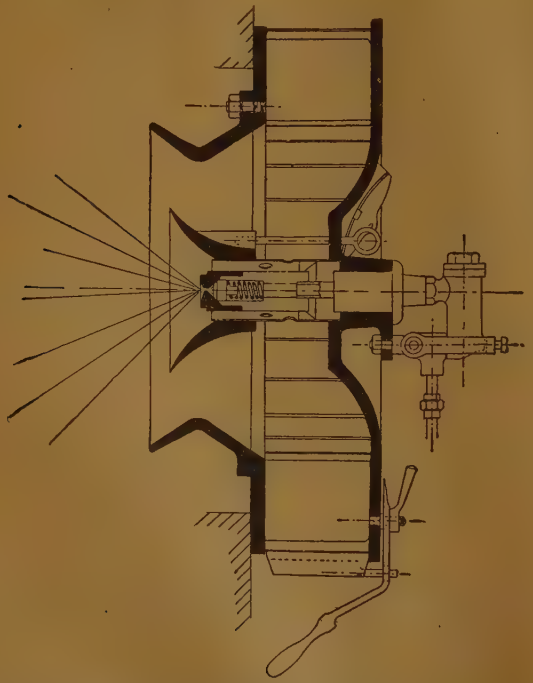


FIG. 373.—*White* air control. The air passes into the hollow furnace front through ducts which give it a rotary motion, and the metal work of this part is intentionally exposed to the radiant heat of the furnace for the purpose of heating the air before it enters the furnace. The flaring sleeve around the burner is adjustable in the line of the axis of the burner and it will be noticed that a small amount of air is admitted directly around the tip through the opening in the sleeve. It is claimed that the "Venturi meter" effect of the portion of the apparatus where the air enters the furnace is of benefit in promoting combustion.

NOTE.—***Valves.*** For valves on suction lines designed for viscous oils, the gate valve is preferable, on account of reduced friction. On delivery lines, globe valves of a regrinding type give satisfaction. There is no occasion to use needle valves. Where fine regulation is required, as in some cases with steam atomizers, there are several types of valve which open gradually on slotted or "V" shaped passages which give better and more consistent results than the needle type. All valves for high pressure work should be extra heavy with bonnets screwed over, not into, the valve body. Specially designed and packed plug cocks may be used in small sizes for quick action.

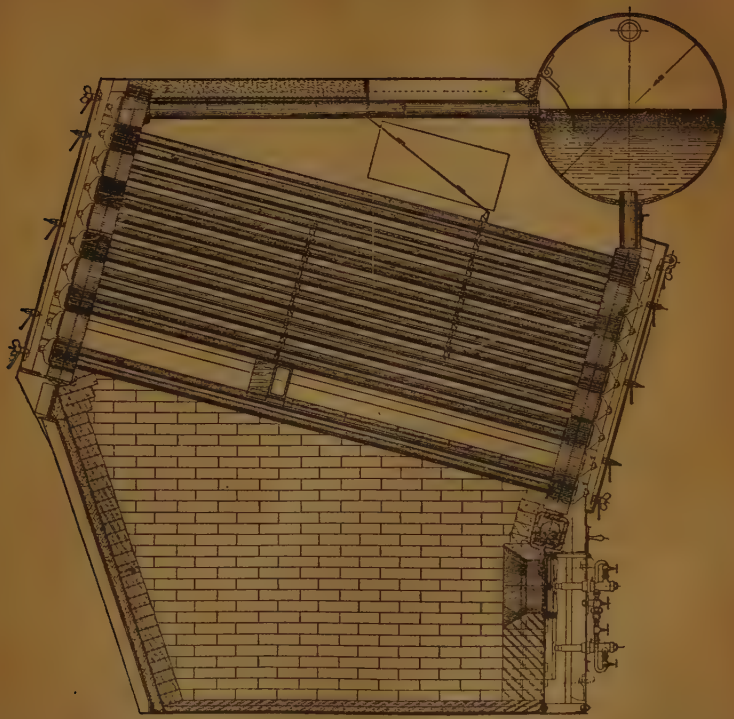


FIG. 374.—Sectional view of ***Babcock & Wilcox*** marine boiler showing furnace and ***Peabody oil burners.*** The reverberating brick baffle on the bottom group of tubes direct the gases to the rear of the furnace, in which direction it will be noted that the furnace increases in height and volume. Moreover, the oil is injected into the furnace along lines nearly parallel or at a slight angle with the tubes which promotes a very even distribution of the flame along the bottom row of tubes.

NOTE.—***Stowage on board.***—By no means the least of the advantages of oil over coal is its adaptability for storage in almost any part of the vessel—in the ordinary bunker space, or in tanks remote from the fireroom, or in double bottoms. Special precautions must be taken to prevent and to detect leakage from the tanks. Special riveting is employed and frequently coffer dams are built around the oil tanks. Coffer dams around the oil tanks are recommended but not insisted upon by any of the Classification Societies, except where "low flash point" oils are allowed, *i. e.*, oils having a flash point below 150° F. In other words, while oil is easily handled, the feasibility of its use on shipboard depends primarily on the ability to keep it where it is stowed until it is pumped to the burners. In deep tanks, swash plates are installed to prevent undue motion of the liquid in the tanks when partly filled. Expansion trunks are provided to allow for increase in volume due to heating; vent pipes are carried above the decks to carry away vapor given off by the oil. These are fitted with goose necks at the top covered with wire gauze, and sometimes in destroyers or vessels of low freeboard the vents have special automatic valves at the end instead of the simple goose neck, for discharging vapor and at the same time preventing water from entering the tanks.

Strainers.—The comparatively small orifice of the mechanical sprayer necessitates special care being taken in straining the oil. Most makes of burner are fitted with individual strainers, that used in the Peabody burner being shown in fig. 304.

The spool is wrapped with three turns of brass netting of 40 to the inch mesh, fastened with No. 20 gauge brass wire.

Furnace Walls.—In laying up brick walls and flooring of oil furnaces, provision should be made for expansion, but it is worth noting in this connection, that there is a great difference in the coefficient of expansion of fire brick. It is possible to secure highly refractory brick and tiles made of material which expands but slightly, not over $\frac{1}{16}$ in. in 9 in.

The Babcock & Wilcox Company uses a light wash for making joints, composed of 15 parts (by weight) of fire clay, 5 parts of carborundum sand, and 1 part silicate of soda.

The special high temperature cements on the market are a needless expense for new work but are very effective for repairs, where they find a special field of usefulness.

It is a good idea to throw a few old glass bottles into the furnace to make a glaze on the bottom surface and fill the cracks.

NOTE.—***Sounding pipes*** for measuring depth of oil in the tanks are provided. These should be of ample size, anything less than $2\frac{1}{2}$ in. being unreliable for deep tanks in which viscous Mexican oil is carried. It is advisable to drill small holes in these pipes to give free access to the oil at all depths, as it is possible for some difference in density to exist at the various levels, if the oil has been standing for some time. Heavier oil at the bottom would give an erroneous reading if the sounding pipe were open at the bottom end only.

NOTE.—***In closed tanks*** the combined area of the vents and sounding pipes must be sufficient to provide an adequate overflow in the case of too rapid filling, which might put an undue pressure on the tank. For this reason, when tanks in the lower part of the vessel, such as the double bottoms, are used for oil, it is advisable to fill through a system of relay tanks which eliminates the danger of a large "head" of oil exerting a heavy pressure on the storage tanks.

CHAPTER THIRTY

PRACTICAL ELECTRICITY

Introductory.—The power plant of nearly all vessels includes both steam engines and electrical generators, all being under the charge of one head. Accordingly the marine engineer can no longer afford to be deficient in a knowledge of electricity. The subject is here presented in condensed form so that the student can quickly obtain a working knowledge of electrical principles and construction.

Electricity.—The name electricity is applied to an invisible agent known only by the effects which it produces, and the various ways in which it manifests itself.

Electrical *currents* are said to flow through *conductors*. These offer more or less *resistance* to the flow, depending on the material. Copper wire is generally used as it offers little resistance.

The current must have pressure to overcome the resistance of the conductor and flow along its surface. This pressure is called *voltage* caused by what is sometimes called *difference* of ***potential*** or better termed *difference of* ***pressure*** between the source and terminal.

An electric current has often been compared to water flowing through a pipe. The pressure under which the current flows is measured in *volts* and the quantity that passes in *amperes*. The resistance with which the current meets in flowing along the conductor is measured in *ohms*.

The flow of the current is proportional to the voltage and inversely proportional to the resistance. The latter depends upon the material, length and diameter of the conductor.

Since the current will always flow along the path of least resistance it must be so guarded that there will be no leakage. Hence to prevent leakage, wires are *insulated*, that is, covered by wrapping them with cotton, silk thread, or other insulating material. If the insulation be not effective, the current may leak, and so return to the source without doing its work. This is known as a ***short circuit.***

The conductor which receives the current from the source is called the *lead*, and the one by which it flows back, the *return*. When wires are used for both lead and return, it is called a *metallic circuit;* when the ground is used for the return, it is called a *grounded circuit*.

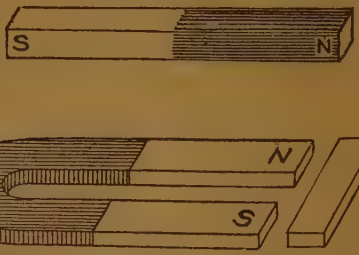
An electric current is said to be:

1. *Direct*, when it is of unvarying direction;

2. *Alternating*, when it flows rapidly to and fro in opposite directions;

3. *Primary*, when it comes directly from the source;

4. *Secondary*, when the voltage and amperage of a primary current have been changed by a transformer, or *induction coil*.



FIGS. 375 and 377.—Simple *bar magnet* and *horse shoe magnet* with *keeper*. These are known as permanent magnets as distinguished from electro-magnets. The horse shoe magnet will attract more than the bar magnet because both poles act together. A piece of soft iron, or keeper, is placed across the ends of a horse shoe magnet to assist in preventing the loss of magnetism

A current is spoken of as *low tension*, or *high tension*, according as the voltage is low or high. A high tension current is capable of forcing its way against considerable resistance, whereas, a low tension current must have its path made easy. A continuous metal path is an easy one, but an interruption in the metal is difficult to *bridge*, because air is a very poor conductor.

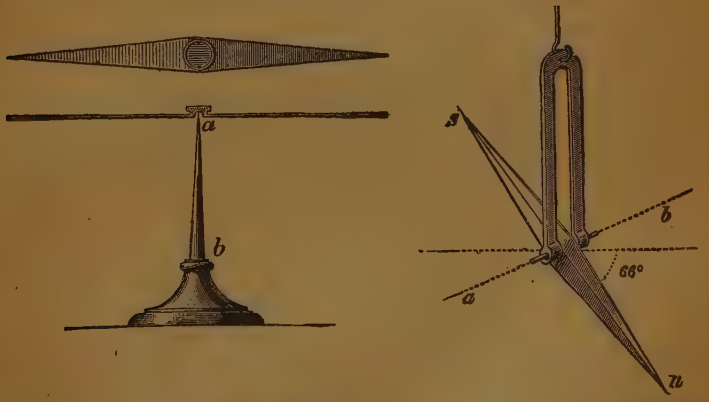
Air is such a poor conductor that it is usually, *though erroneously*, spoken of as a "non-conductor" it is properly called an *insulator*.

Magnetism.—The ancients applied the word "magnet," *magnes lapes*, to certain hard black stones which possess the property of attracting small pieces of iron, and as discovered later, to have the still more remarkable property of pointing

north and south when hung up by a string; at this time the magnet received the name *lodestone.*

Magnets have two opposite kinds of magnetism or magnetic poles which attract or repel each other in much the same way as would two opposite kinds of electrification.

One of these kinds of magnetism has a tendency to move toward the north and the other, toward the south. The two regions, in which the magnetic property is strongest, are called the *poles.* In a long shaped magnet it resides in the ends, while all around the magnet half way between the poles there is no attraction at all.



FIGS. 378 to 380.—Horizontal magnetic needle, and magnetic "dip" needle. A magnetic needle consists of a small bar magnet, supported upon a pivot or suspended so that it is free to turn in a horizontal or vertical plane. The form of magnetic needle illustrated in fig. 378 is arranged to show the magnetic meridian; the needle moves upon a perpendicular axis or pivot *ab.* In fig. 380, the needle *sn* turns upon a horizontal axis *ab.* This needle indicates the dip or inclination, that is, the angle which it makes with the horizontal plane, due to the fact that in most places the lines of force are not horizontal. In the northern hemisphere the N pole of the needle is depressed, in the southern hemisphere, the S pole is similarly affected. When used, the dip needle must be set so that the plane in which the needle swings contains the magnetic meridian, as indicated by the horizontal needle.

The poles of a magnet are usually spoken of as *north pole* and *south pole.*

When a current of electricity passes through a wire, a certain change is produced in the surrounding space producing what is known as a magnetic field. If the wire be insulated with a covering and coiled around a soft iron rod, it becomes an electro-magnet having a north and south pole, *so long as the current continues to flow.* The magnetic strength increases with the number of turns of the coil, for each turn adds its magnetic field to that of the other turns.

Induction.—If a second coil of wire be wound around the coil of an electro-magnet, but not touching it, an *induced current* is produced in this second coil by what is known as *induction*, each time the current in the inside coil begins or ceases flowing.

The inside coil is called the *primary winding* and the outside coil, the *secondary winding*. Similarly, the current passing through the inside coil is called the *primary current*, and that in the outside coil, the *secondary* or *induced current*.

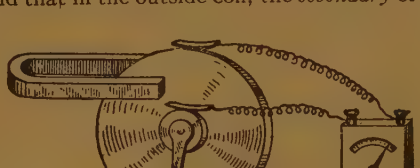


FIG. 381.—Faraday's dynamo which embodies his discovery in 1831 of *electromagnetic induction*, the principle upon which all dynamos work, as well as induction coils, transformers, and other electrical apparatus.

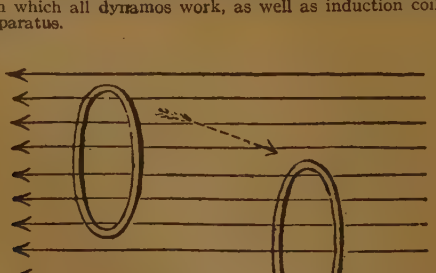


FIG. 382.—***Electro-magnetic induction:*** In order to induce a current by electro-magnetic induction, a conductor must be so moved through a magnetic field *that the number of lines of force passing through it (that is, embraced) are* **altered.** If a coil be given a simple motion of translation in a uniform magnetic field as indicated in the figure, no current will be induced *because the number of lines of force passing through it are not changed*, that is, during the movement, as many lines are lost as are gained.

It has been found that by varying the ratio of the number of turns in the two coils the tension or voltage of the two currents is changed proportionately. That is, if the primary winding be composed of ten turns and the secondary of one hundred, the voltage of the secondary current is increased ten times that of the primary. This principle is employed in the construction of induction coils and transformers.

What is a volt?

An electromotive force or pressure which will produce a current of one ampere in a circuit having a resistance of one ohm.

What is an ohm?

The resistance offered to an electric current by a column of mercury one square millimeter in section and 106 centimeters long, at a temperature of 0° C.

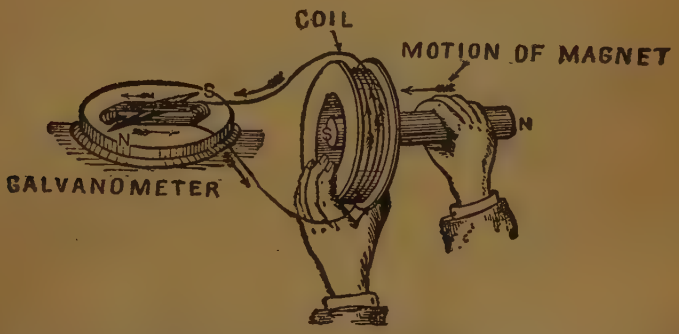


FIG. 383.—Experiment illustrating ***Lenz's law*** which states that in all cases of electro-magnetic induction, *the direction of the induced current is such as to tend to stop the motion producing it.* ***In the experiment,*** in order to produce the induced current, energy must be expended in bringing the magnet to the coil and in taking it away, which is in accordance with the law of conservation of energy.

What is an ampere?

The current produced by an electromotive force or pressure of one volt in a circuit having a resistance of one ohm.

An ampere is that quantity of current which will deposit .001118 gramme of silver per second.

State Ohm's Law, and the formulæ derived from it.

Considering a steady flow of electricity in a given circuit, then according to Ohm's law: *the amount of current in amperes is equal to the pressure in volts divided by the resistance in ohms.*

The law may be expressed in three simple formulæ, when I, is used as the

symbol of the current strength in amperes, R, as that of the resistance in ohms, and E, the pressure in volts, as follows:

$$I = \frac{E}{R},$$

which reads: The current in amperes equals the pressure in volts divided by the resistance in ohms.

$$E = IR,$$

which reads: The pressure in volts equals the current in amperes multiplied by the resistance in ohms.

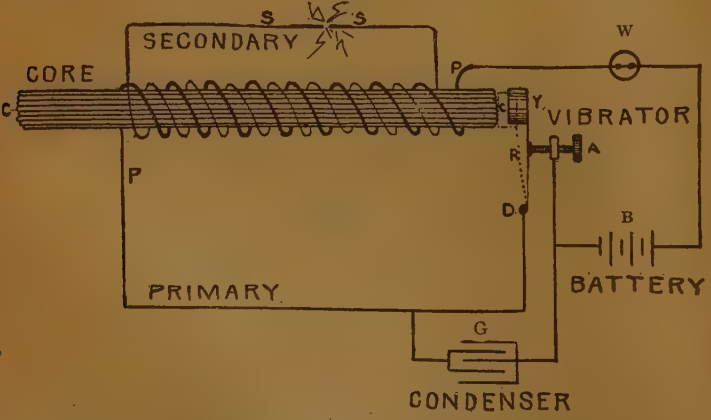


FIG. 384.—Diagram of a vibrator coil. ***The parts are as follows:*** A, contact screw; B, battery; C, core; D, vibrator terminal; G, condenser; P, primary winding; S, secondary winding; W, switch; Y, vibrator. When the switch is closed, the following cycle of actions takes place: *a*, the primary current flows and magnetizes core; *b*, magnetized core attracts the vibrator and breaks primary circuit; *c*, the magnetism vanishes, inducing a momentary high tension current in the secondary winding; *d*, magnetic attraction of the core having ceased, vibrator spring re-establishes contact; *e*, primary circuit is again completed and the cycle begins anew.

$$R = \frac{E}{I},$$

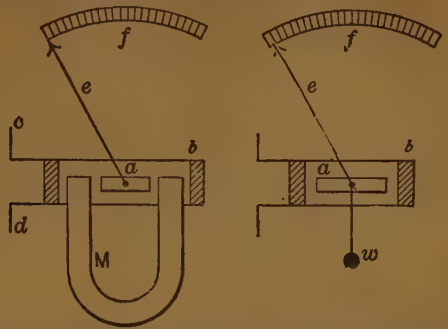
which reads: The resistance in ohms equals the pressure in volts divided by the current in amperes.

What is a watt?

The product of one ampere multiplied by one volt.

What is the electrical horse power?

The unit of electrical work, being the mechanical horse power expressed in watts. It is equal to 746 watts.



FIGS. 385 and 386.—Diagram showing construction of voltmeters and ammeters. The soft iron needle *a*, is pivoted within a coil of very fine wire *b*, and held normally out of line with the axis of the coil by means of a permanent magnet M, or a weight *w*. Passing a current through the coil *b*, causes magnetic lines to flow (vertically in the illustrations) through its center, and these tend to pull the needle around into line with them. The permanent magnet M, or the weight *w*, resists this pull, and the distance that the needle is deflected indicates the strength of the current in the coil. A pointer *e*, is attached to the needle *a*, and the scale *f*, is marked in volts; the pointer *e*, indicates on the scale the voltage at the terminals *c*, *d*, of the coil *b*.

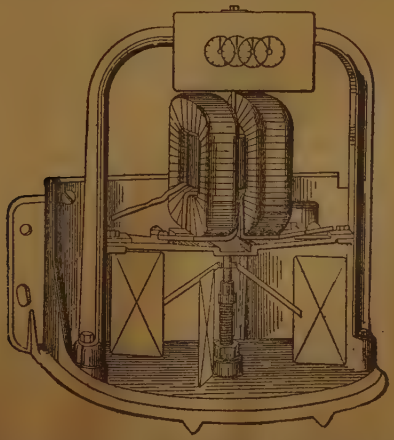


FIG. 387.—***Recording watt hour meter.*** It consists of a very small motor which drives a delicate train of gears, the hands of which indicate on dials the number of watt hours supplied. The two coils of wire enclose the armature and furnish the field magnetism. The fan blades on the lower part of the shaft serve as a brake to steady the rotation of the shaft. There are several forms of motor meter, all based on the same principle—that of making the speed of the motor proportional to the watts supplied to the circuit.

What is meant by the carrying capacity of a wire?

The amount of current it will carry without heating to such an extent as to cause danger of burning the insulation or wood work.

What is meant by the "drop" in a circuit?

The drop in a circuit means the number of volts lost in overcoming the resistance of the circuit. It corresponds to the drop in pressure along a steam pipe or water main.

Table of Current Capacity of Wires

No. of wire, B. & S. gauge.	Rubber covered Wire. Amperes.	Weather proof Wire. Amperes.
18	3	5
16	6	8
14	12	16
12	17	23
10	24	32
8	33	40
6	46	64
5	54	77
4	65	92
3	76	110
2	90	131
1	107	156
0	129	185
00	150	220
000	177	262
0000	210	312

Describe a dynamo.

A dynamo consists of three essential parts, a *field magnet*, an *armature*, and a *commutator*. The field magnet must be magnetized either by the dynamo itself or some outside source. The armature consists of coils of insulated copper wire wound upon a core of thin iron discs which is mounted on a shaft and caused to rotate between the poles of the field magnet in such a manner that the lines of magnetic force passing through the coils of the armature are constantly increasing or decreasing. This action causes *alternating* currents of electricity to be generated in the coils of the armature, which are collected by suitable brushes at

the commutator and converted into *direct* current for the external circuit.

What is meant by the magnetic circuit?

The path through which the magnetic lines or force travel.

What is the object of making the armature core of thin discs rather than of solid metal?

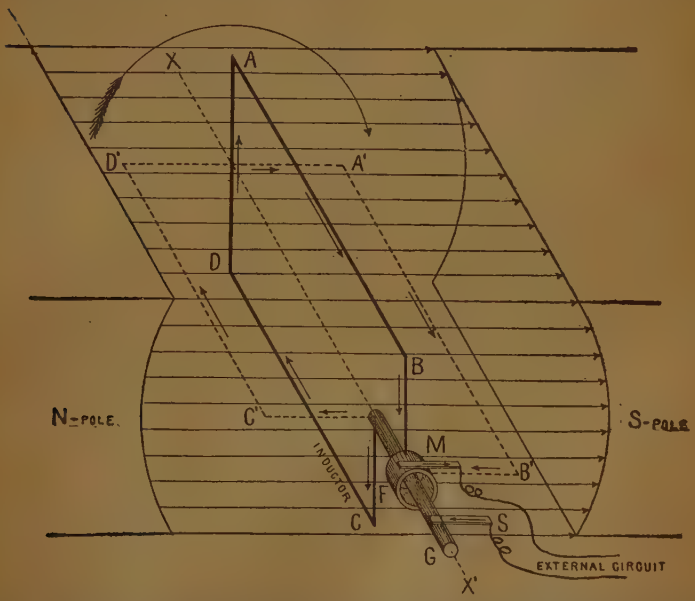


FIG. 388.—***Simple elementary alternator.*** Its parts are a single conducting loop, ABCD, placed between the poles of a permanent magnet, and having its ends connected with a ring, F, and shaft, G, upon which bear brushes M and S, connected with the external circuit. When the loop is rotated clockwise the induced current will flow in the direction indicated by the arrows during the first half of the revolution.

To prevent *eddy currents* which convert energy into heat; this would not only produce a waste of energy, but would also injure and perhaps destroy the insulation of the armature coils.

How are dynamos classified according to the winding of their field magnets?

Into three classes; series, shunt, and compound dynamos.

What is a series dynamo?

A dynamo in which all the current produced by the machine flows through its field magnet coils.

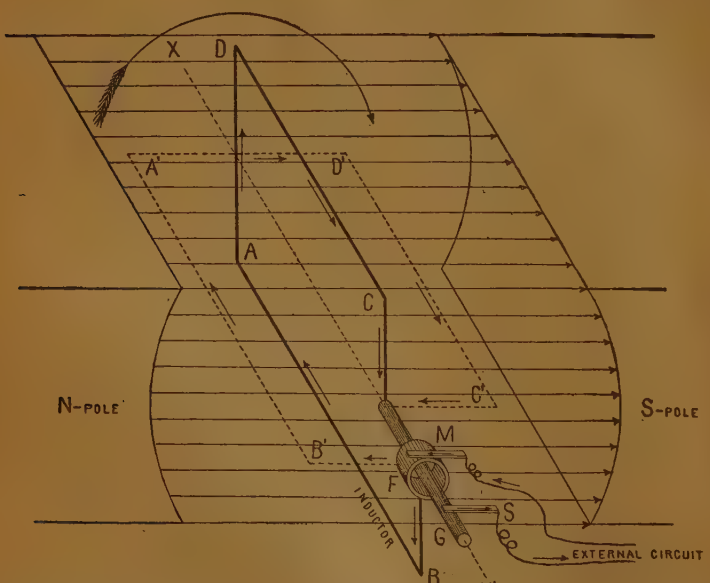


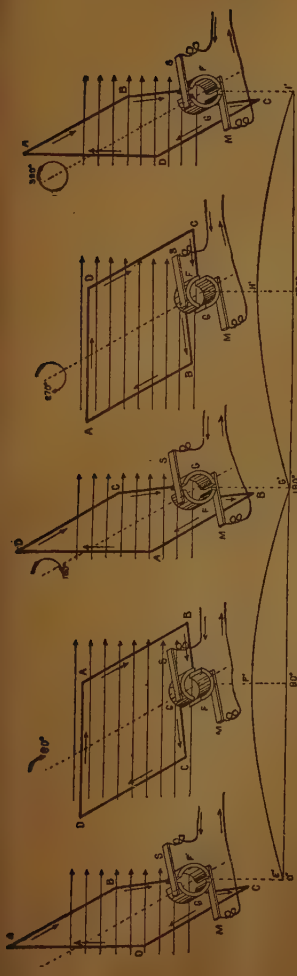
FIG. 389.—Simple elementary alternator, showing reversal of current when the loop has made one-half revolution from the position of fig. 388. It should be noted that A B, for instance, which has been moving *downward* during the first half of the revolution (fig. 388), moves *upward* during the second half (fig. 389); hence, the current during the latter interval flows in the opposite direction.

What is a shunt dynamo?

One in which only a portion of the total current of the machine passes through the field magnet coils.

What is a compound dynamo?

A dynamo having two windings: a series winding, around



FIGS. 390 to 394.—Commutation of the current. These figures show how a dynamo transforms alternating into the so called direct current. During the first half of the revolution the current flows in the direction AB, out through segment F, of the commutator and brush M, returning through brush S and segment G, figs. 390 and 391. At the beginning of the second half of the revolution, fig. 392, the current in the armature reverses and flows around the loop in the direction BA. At this instant the brushes M and S, pass the gaps between the commutator segments, thus reversing contact with the segments, and causing the current in the external circuit to remain in the same direction.

which the main current flows; and a shunt winding, through which a fraction of the main current flows.

For what class of work is a shunt dynamo used?

For work requiring a constant pressure at all loads.

Does a shunt machine maintain a constant pressure at all loads?

Nearly so; the pressure falls off a little as the load increases.

What system of distribution requires a constant pressure at all loads?

The ordinary parallel or multiple system.

What is the principal disadvantage of a parallel system as compared with a series system?

The greater cost of the copper conductors.

Are shunt dynamos used in general for this class of work?

No; they have been superseded largely by the compound dynamo, which gives a closer regulation of pressure.

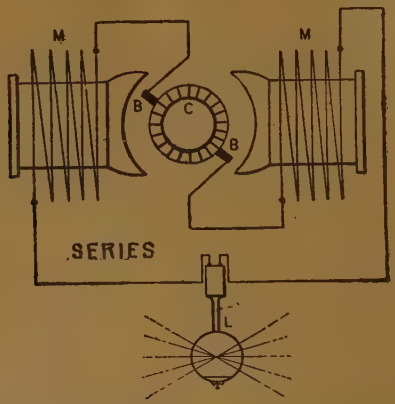


FIG. 395.—***Series Dynamo;*** also called constant current machine because the voltage rises with the load. This type of machine requires a regulator which is usually an electro-mechanical device for shifting the brushes to conform with the load. MM, field coils; BB, brushes; C, commutator; L, lamp. The field coils consist of a few turns of heavy wire joined in series with the armature so that the whole current passes through the coils to the external circuit, thus maintaining the field; the strength of field increases with the load.

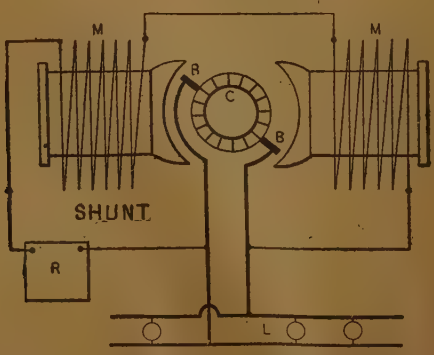


FIG. 396.—***Shunt Dynamo.*** Generally used for incandescent lamps and motors. MM field coils; BB, brushes; C, commutator; L, lamp circuit; R, field rheostat. The field coils consist of many turns of fine wire connected in parallel to the external current, thus obtaining a small portion of the armature current for maintaining the field. The voltage is regulated by adding or cutting out resistance in the field by means of the rheostat R.

What is meant by an overcompounded dynamo?

One which automatically raises the pressure a little in proportion as the load increases, due to increasing the series winding.

What are its advantages over one that would maintain the pressure constant?

Such a dynamo would make up for a slight fall in the speed of an engine, which takes place as the load increases; it also makes up for a loss in pressure on the circuit wires, which loss is proportional to the load which they carry.

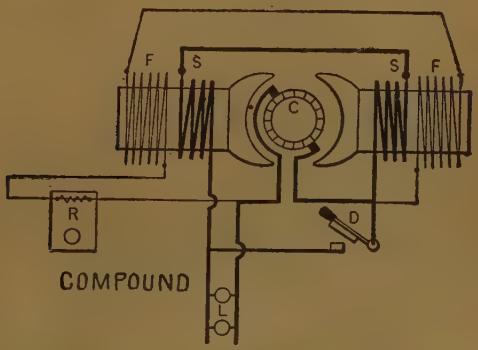


FIG. 397.—***Compound wound dynamo.*** This has two windings on the field magnets, and is a combination of the series and the shunt dynamos. SS, series winding; FF, shunt winding; R, shunt rheostat; C, commutator; L, external circuit; D, series cut out switch, which permits dynamo to be used as simple shunt machine. The series coils strengthen the field as the load rises, and by varying the number of series turns, different results may be obtained. If the series coils be of many turns, the field magnets will be so strengthened as to cause the voltage to rise with increase of load. This is called *over compounding.*

How is overcompounding actually obtained?

By increasing the number of turns in the series coil of a compound dynamo above what would be necessary to give a constant pressure machine.

Can the pressure furnished by a shunt or compound dynamo be varied? and if so, how?

Yes; it could be varied by altering the speed of the engine, but the common method is to insert an adjustable resistance called a

"rheostat" in series with the shunt field coils. When the arm of the rheostat is turned one way, more resistance is thrown into the shunt circuit, which cuts down the current flowing around the coils. As this diminishes the strength of the field magnet the pressure furnished by the machine is lessened. Moving the rheostat arm in the other direction cuts out resistance and raises the pressure.

What care must be given to a dynamo in order to make it run properly?

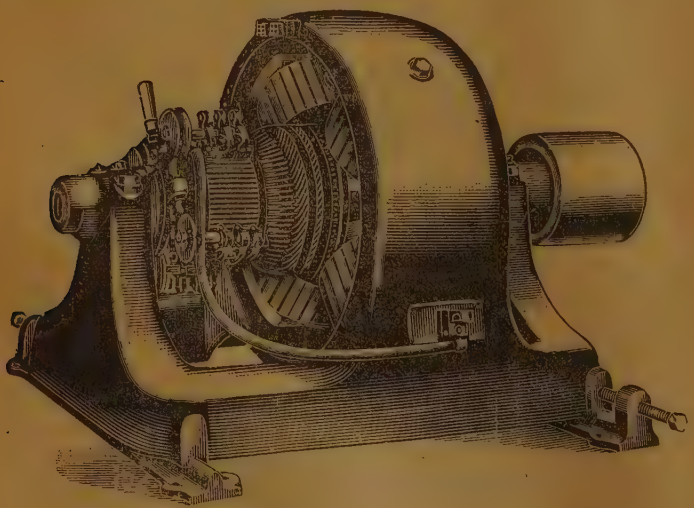


FIG. 393.—A four pole dynamo, mounted on V rails with adjustment for tightening the belt.

It must be kept clean and dry. The bearings, of course, need no more nor no less attention than similar bearings in other machinery. The parts which require the most care are the commutator and brushes.

What conditions result in "sparking" at the brushes?

1, The brushes may not be set at point of commutation; 2,

brushes may be wedged in holders; 3, brushes may not be properly fitted to commutator; 4, brushes may not bear with sufficient pressure; 5, brushes may be burned on ends; 6, commutator may be rough; 7, commutator may have a loose or projecting bar; 8, commutator may be dirty, oily or worn; 9, machine may be badly designed or overloaded; 10, loose connection of coil to commutator, or open circuit.

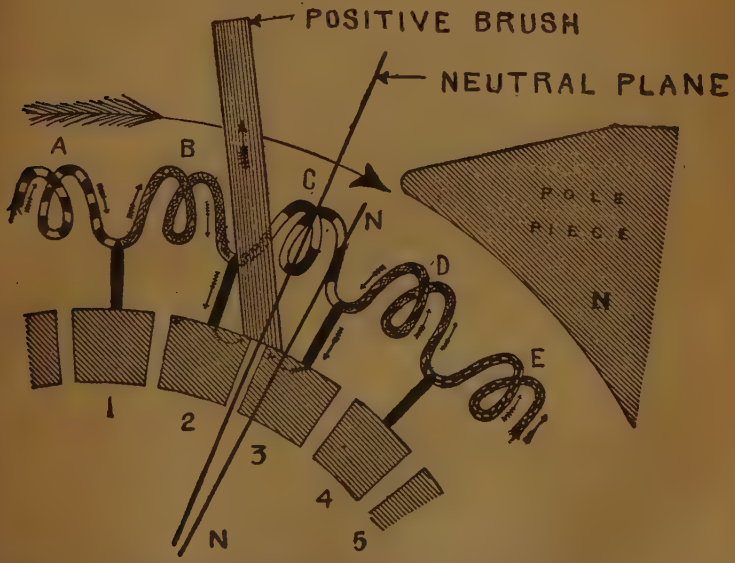


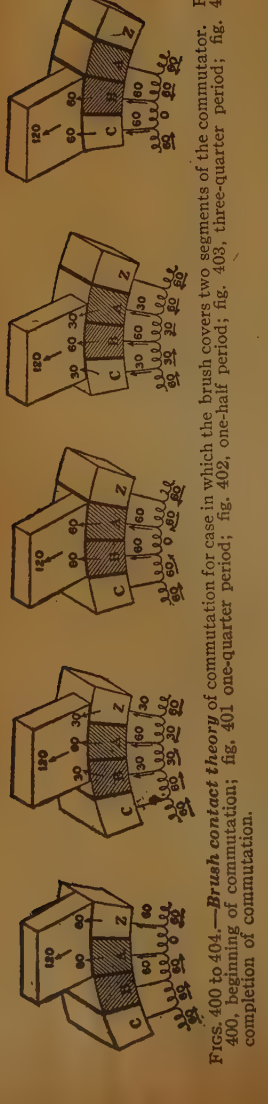
FIG. 399.—***Commutation.*** This takes place during the brief interval in which any two segments of the commutator are bridged by the brush. The coil connecting with the two segments under the brush is thus short circuited. ***During commutation,*** the current in the short circuited coil is brought to rest and started again in the reverse direction against the opposition offered by its so called inertia, or effect produced by self-induction.

What is the cause of sparking at the brushes?

It is due to *self-induction* in the coil undergoing commutation.

Explain the effect of self-induction in detail.

When commutation takes place with the brushes in the neutral



FIGS. 400 to 404.—***Brush contact theory*** of commutation for case in which the brush covers two segments of the commutator. Fig. 400, beginning of commutation; fig. 401 one-quarter period; fig. 402, one-half period; fig. 403, three-quarter period; fig. 404, completion of commutation.

plane as in fig. 399, there will be no volt age induced in the short circuited coil C The current, therefore, which flowed in coil C, before it was short circuited will cease, and as segment 3 breaks contac with the brush, it will be thrown as a perfectly idle coil upon the right hand half of the ring in which a current is flow ing toward the brush. Moreover, the current which was flowing through D, and 3, directly to the brush must suddenly tra verse the longer path through the idle coi C. Now, on account of ***self-induction*** *the current acts in precisely the same manne as though it had* ***weight;*** that is: *it canno be instantly stopped or started.* Therefore when segment 3, leaves the brush, the current will not instantly change its pat and flow through C, but will be urged b its "*momentum*," and jump the air ga between the brush and segment 3, thu producing a spark.

How may this sparking be prevented?

If the brushes be given additional lead that is shifted further to the right to som position as N N, fig. 399, coil C, will no remain idle during the interval it is shor circuited, *but will cut the magnetic lines i such a way as to induce a current in th reverse direction through it.* Under thes conditions, when segment 3, breaks con tact with the brush, the current flowin through D, does not encounter an idle co

but one in which a current is flowing in the same direction, hence, the tendency to jump the air gap and produce a spark is reduced; with proper adjustment of the brushes, there will be no sparking.

Why are carbon brushes so extensively used?

Because they are the only form of brush that will give good commutation with fixed lead.

Mention one trouble sometimes encountered with brush holders.

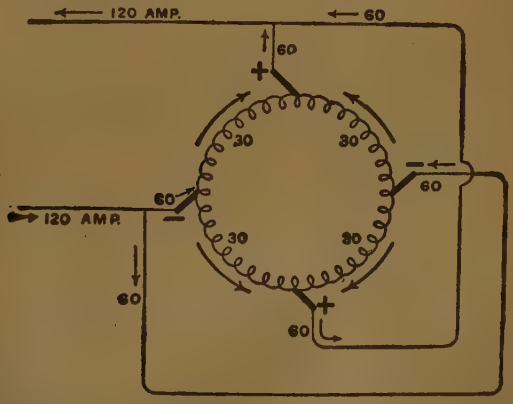
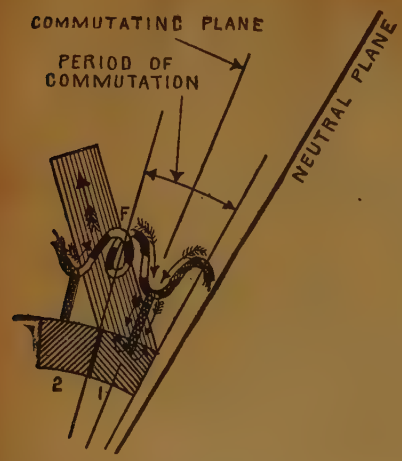


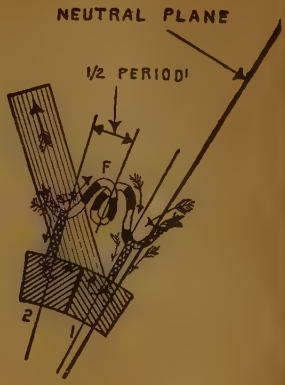
FIG. 405.—Distribution of armature currents in a four pole lap wound dynamo having four brushes and generating 120 amperes.

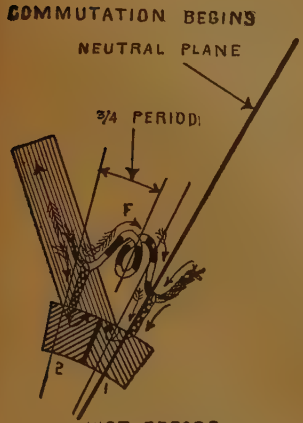
There is sometimes trouble resulting from the current passing through the spring which heats it and destroys its elasticity.

Adjusting the Brushes.—The *adjustment of the brushes* upon the commutator requires careful attention if sparking is to be avoided. There are two adjustments to be made:

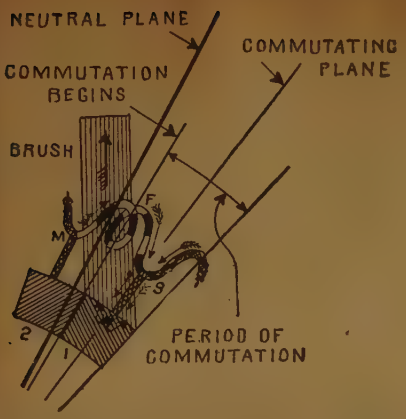
1. For pressure.

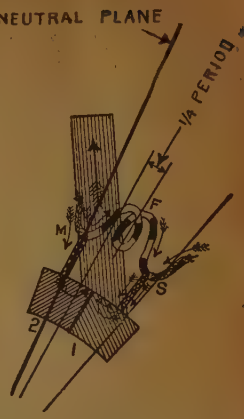






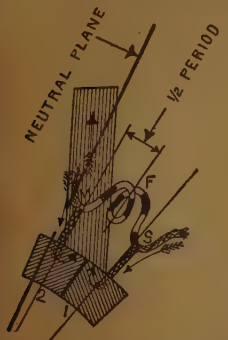
FIGS. 406 to 409.—***Improper brush adjustment*** resulting in excessive sparking. When the brushes are not advanced far enough, commutation takes place before the short circuited coil reaches the neutral plane, hence, its motion is not changed with respect to the magnetic field so as to induce a reverse current until after commutation. There is then no opposing force, during commutation, to stop and reverse the current in the short circuited coil, and when the brush breaks contact with segment 1, as in fig. 409, the "*momentum*" of the current in coil F, causes it to jump the air gap from segment 1, to segment 2, and the brush, against the enormous resistance of the air, thus producing a spark whose intensity depends on the momentum of the current in coil F. Sparking, if allowed to continue, will injure the brushes and commutator segments.

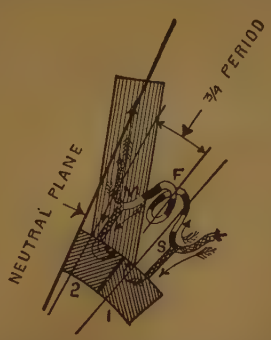




FIGS. 410 to 414.—***How sparkless commutation is obtained*** by advancing the brushes beyond the neutral plane; commutation progressively shown.

FIG. 410.—***Commutation begins;*** current flows up both sides of the armature, uniting at S, and flowing to the brush through commutator segment 1, as indicated by the arrow.





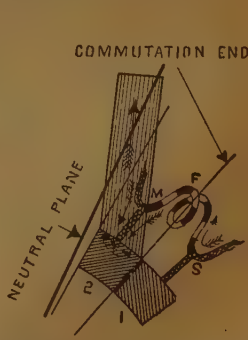


FIG. 411.—Segment 2, has come into contact with the brush and coil F, in which commutation is taking place, is now short circuited. The current now divides at M, part passing to the brush through segment 2, and part through coil F, and segment 1. Although coil F, is short circuited and having passed the neutral plane, is cutting the lines of force so as to induce a current in the opposite direction, it still continues to flow with unchanged direction against these opposing conditions. This is due to *self-induction* in the coil which resists any change just as the momentum of a heavy moving body, such as a train of cars, offers resistance to the action of the brakes in retarding and stopping its motion.

FIG. 412.—Segment 2, has moved further under the brush, and the opposition offered to the forward flow of the current in the short circuited coil F, by the reverse induction in the magnetic field to the right of the neutral plane has finally brought the current in F, to rest. The current from each side of the armature now flows direct to the brush through their respective end segments 1 and 2.

FIG. 413.—Segment 1, is now almost out of contact with the brush. A current has now been started in the coil F, in the reverse direction due to induction in the magnetic field to the

The brushes must bear against the commutator segments with sufficient pressure for proper contact.

2. For lead.

The brushes must have the proper angular advance (positive or negative, according as the machine is a dynamo or motor) to prevent sparking.

At what point on the commutator should the brushes bear?

The points upon the commutator at which the tips of the brushes (carried by opposite arms of the rocker) bear, should be, in bipolar dynamos, at opposite extremities of a diameter. In multipolar dynamos the positions vary with the number of poles and the nature of the armature winding.

What provision is made to facilitate the correct setting of the brushes?

Setting marks are usually cut in the collar of the commutator next to the bearing.

With what pressure should the brushes bear against the commutator?

The tension of the springs should be just sufficient to cause the brushes to make a light yet reliable contact with the commutator.

Attention while Running.—When a dynamo is started and at work, it will need a certain amount of attention to keep it running

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FIGS. 410 to 414.—*Text continued.*

right of the neutral plane; it flows to the brush through segment 2. The current has not yet reached its full strength in F, accordingly, part of the current coming up from the right divides at S, and flows to the brush through segment 1.

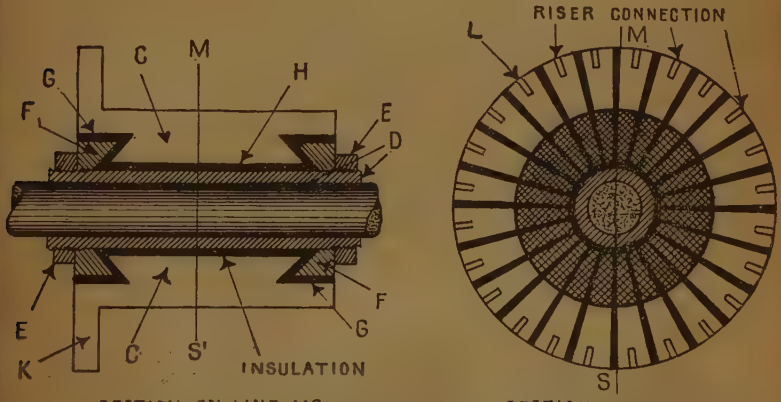
FIG. 414.—***Completion of commutation*** in segments 1 and 2; the brush is now in full contact with segment 2, the current in coil F, has now reached its full value, hence the current flowing up from the right no longer divides at S, but flows through F, and segment 2 to the brush. If the current in F, had not reached its full value, at the instant segment 1, left contact with the brush, it could not immediately be made to flow at full speed any more than could a locomotive have its speed instantly changed. This, as previously explained, is due to self-induction in the coil or the so-called "inertia" of the current which opposes any sudden change in its rate of flow or direction. Accordingly that portion of the current which was flowing up from the right and passing off at S, to the brush, through segment 1, as in fig. 413, would, when this path is suddenly cut off as in fig. 414, encounter enormous opposition in coil F. Hence, it would momentarily continue to flow through segment 1, and jump the air gap between this segment and the brush, resulting in a more or less intense spark depending on the current conditions in coil F.

in a satisfactory and efficient manner. The first point to be considered is the adjustment of the brushes. If this be neglected, the machine will probably spark badly, and the commutator and brushes will frequently require refitting to secure good contact.

What may be said with respect to the lead of the brushes?

The lead in all good dynamos is very small, and varies with the load and class of machine.

The best lead to give to the brushes can in all cases be found by rotating the rocker and brushes in either direction to the right or left of the neutral plane



FIGS. 415 and 416.—Side and end sectional views of commutator showing construction. *The parts are:* C, segments; D, tubular iron hub; E, end nuts; F, clamps; G, insulation; L, riser connection.

until sparking commences, increasing with the movement. The position midway between these two points is the correct position for the brushes, for at this position the least sparking occurs, and it is at this position that the brushes should be fixed by clamping the rocker.

What should be done if the brushes begin to spark excessively?

First, look at the ammeter to see if an excessive amount of current is being delivered; second, see if the brushes make good contact with the commutator, and if the latter have a bar too high, or too low, and an open circuit.

What should be done if the current be excessive?

If the current exceed the rated capacity by more than 50 per cent., and continue for more than a few minutes, the main switch should be opened, otherwise the machine may be seriously injured.

How does an excessive current injure a dynamo?

By causing it to overheat which destroys the insulation of the armature, commutator, etc.

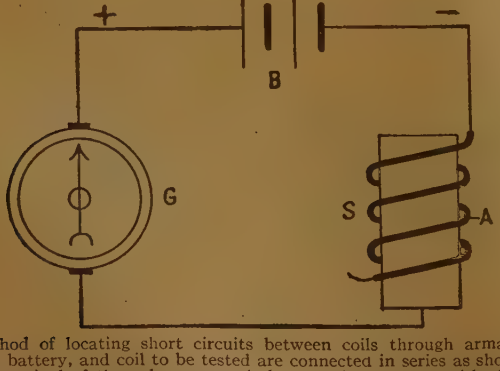


FIG. 417.—Method of locating short circuits between coils through armature core. The galvanometer, battery, and coil to be tested are connected in series as shown, and then the unconnected terminal of the galvanometer is brought into contact with the shaft. If then some portion of the insulation of the wire has been abraded or destroyed, thus bringing the bare wire into contact with the metal core, as at A, in the figure, the needle of the galvanometer will be deflected since a closed circuit is formed through the core and wire.

Starting a Dynamo.—A dynamo is usually brought up to speed either by starting the driving engine, or by connecting the dynamo to a source of power already in motion. In the first case, it should be done by a competent engineer, and in the second case

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NOTE.—***How to reverse a dynamo.*** The direction of rotation of ordinary series, shunt, or compound bipolar dynamos may be reversed by simply reversing the brushes without changing any of the connections, then changing the point of contact of the brush tips 180°.

NOTE.—***In multipolar dynamos,*** a similar change, amounting to 90° for a four pole machine, and 45° for an eight pole machine, will reverse their direction of rotation. It will be understood that under these conditions, the original direction of the current and the polarity of the field magnets will remain unchanged.

by a person experienced in putting on friction clutches to revolving shafts, or in slipping on belting to moving pulleys.

How should a series machine be started?

The external circuit should be closed, otherwise a closed circuit will not be formed through the field magnet winding and the machine will not build up.

What is understood by the term "build up"?

In starting, the gradual voltage increases to maximum.

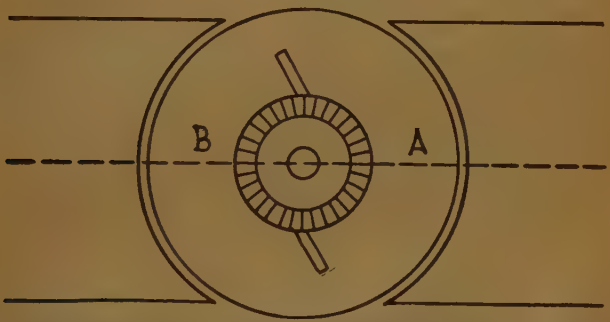


FIG. 418.—Method of locating short circuits between adjacent armature coils. Fasten a Moncky wrench to the rim of the pulley, or a crank to the shaft. Now, excite the fields, and to make the effect more marked, connect the coils in parallel. When this has been done it will require considerable force to rotate the armature, and then it will move quite slowly, except at one position. When this position has been found, mark the armature at points in the center of the pole pieces at points A and B, and at both ends of the armature. The explanation is that both halves of the armature oppose one another at this position; but when not at these points, a continuous circuit is formed, and the resultant magnetic effect is considerable. The "cross" or "short" circuit is nearly always found on the commutator end in the last half of the winding, where the wires pass down through the first half terminals. This applies to an unequal winding. In armatures where the windings are equal, it is as liable to occur at one point as at another. With this method a defect can be found and remedied in a few moments, for it has always been a simple matter to repair it when discovered. These results can be observed in a perfect armature by connecting the opposite sections of the commutator.

How should a shunt or compound machine be started?

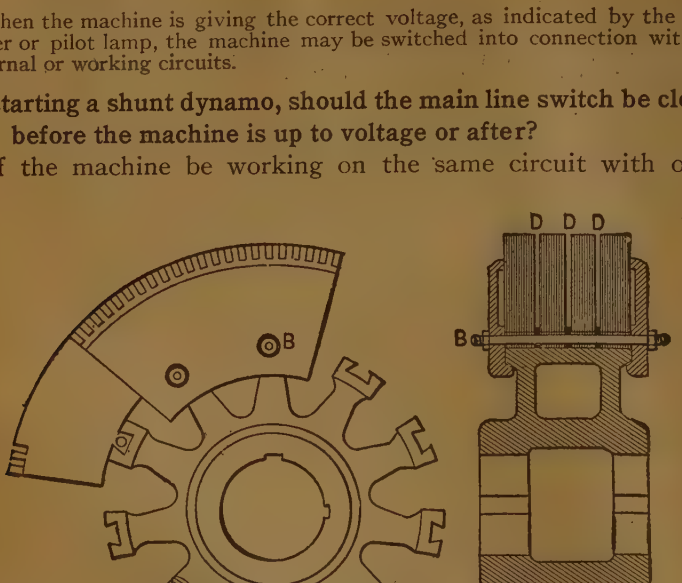
All switches controlling the external circuits should be opened, as the machine excites best when this is the case. If the machine be provided with a rheostat or hand regulator and resistance coils, these latter should all be cut out of circuit, or short circuited,

until the machine excites, when they can be gradually cut in as the voltage rises.

When the machine is giving the correct voltage, as indicated by the voltmeter or pilot lamp, the machine may be switched into connection with the external or working circuits.

In starting a shunt dynamo, should the main line switch be closed before the machine is up to voltage or after?

If the machine be working on the same circuit with other



FIGS. 419 and 420.—Side and end view of built up armature core. The sheet metal ring sections containing the teeth are fastened into dovetail notches in the spider as shown. The layers of ring sections are placed so as to break joints and are held by end clamps and through bolts B. Distance pieces are inserted at intervals to provide ventilating spaces D,D,D.

machines, or with a storage battery, it is, of course, necessary to make the voltage of the machine equal to that on the line before connecting it in the circuit.

If the machine work alone, the switch may be closed either before or after the voltage comes up. The load will be thrown on suddenly if the switch be closed after the machine has built up its voltage, thus causing a strain on the belt, and possibly drawing

water over into the engine cylinder. On the other hand, if the switch be closed before the voltage of the machine has come up, the load is picked up gradually, but the machine may be slow or may even refuse to pick up at all.

If a shunt dynamo will not pick up, what is likely to be the trouble?

The speed may be too slow; the resistance of the external circuit may be too small; the brushes may not be in proper position; some of the electrical connections in the dynamo may be

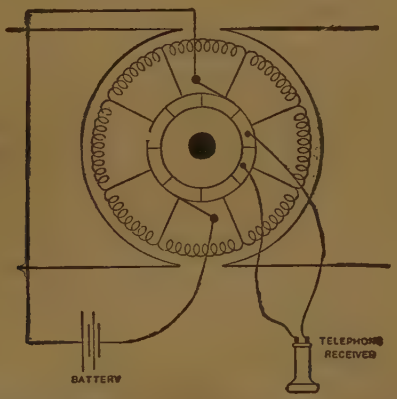


FIG. 421.—Bar to bar test for open circuit in coil or short circuit in one coil or between segments. If, in testing for break in armature lead, on rotating the armature completely around, the receiver indicate no break in the leads, connect the battery leads directly to the brushes, as shown in the above figure, and touch the connections from the receiver to two adjacent bars, working from bar to bar. The clicking should be substantially the same between any two commutator bars; —if the clicking suddenly rise in tone between two bars, it indicates a high resistance in the coil or a break (open circuit).

loose, broken or improperly made; the field may have lost its residual magnetism.

What is the allowable degree of heating?

It may be taken as a safe rule that no part of a working dynamo should have a temperature of more than 80° Fahr. above that of the surrounding air.

Accordingly, if the temperature of the engine room be noted before applying the thermometer to the machine, it can at once be seen if the latter be working at a safe temperature. In taking the temperature, the bulb of the thermometer should be wrapped in a woolen rag. The screws and nuts securing the different connections and cables should be examined occasionally as they frequently work loose through vibration.

Instructions for Stopping Dynamos.—When shutting down a machine, the load should first be gradually reduced, if possible by easing down the engine; then when the machine is supplying

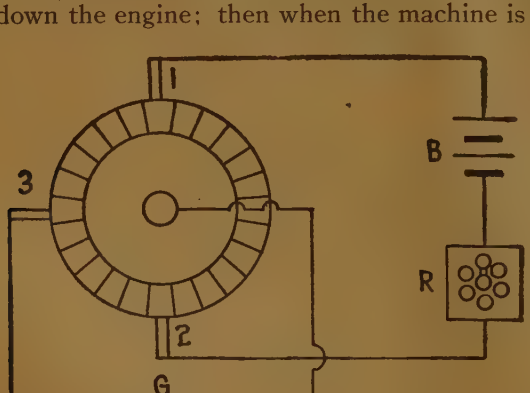


FIG. 422.—*Method of Locating grounded armature coil.* B, is a battery or dynamo circuit giving a current of a few amperes through the armature by its own brushes (1 and 2). A G, is placed a roughly made galvanometer, to carry some 25 amperes or so, one terminal being in connection with the shaft of the armature, and the other attached to a movable brush 3. Since the function of the particular galvanometer is simply to show a deflection when a current is passing, and to mark zero when there is none, a coil of thick wire with a pocket compass in the center will do all that is required, but care must be taken to remove it sufficiently far away from the disturbing effects of the armature magnetism. The manner of testing is as follows: Assume a steady current to be flowing from battery B, through the armature, touch the commutator with brush 3, and a current will flow through G. Slowly rotate the armature or the brush 3, until the galvanometer G, shows no deflection. The coil in contact with 3, will be found to be *grounded*. A hand regulator or rheostat R, may be inserted in series with the battery or dynamo circuit to regulate the strength of the current passing.

little or no current, the main switch should be opened. This reduces the sparking at the switch contacts, and prevents the engine racing.

When the voltmeter almost indicates zero, the brushes should be raised from contact with the commutator. This prevents the brushes being damaged

in the event of the engine making a backward motion, which it often does, particularly in the case of a gas engine. On no account, however, should the brushes be raised from the commutator while the machine is generating any considerable voltage; for not only is the insulation of the machine liable to be damaged, but in the case of large shunt dynamos, the person lifting the brushes is liable to receive a violent shock.

What attention should the machine receive after it has been shut down?

It should be thoroughly cleaned. Any adhering copper dust, dirt, etc., should be removed from the armature by dusting with a stiff brush, and the other portions of the machine should be thoroughly cleaned with linen rags.

Waste should not be used, as it is liable to leave threads or fluff on the projecting parts of the machine, and on the windings of the armature, which is difficult to remove.

What will be the result if the connections of some of the field coils of a dynamo be reversed?

If one-half the number of coils oppose the other half, the field magnetism will be neutralized and the machine will not build up at all; but if one of the coils be opposed to the others, the machine might build up, but the generated voltage will be low, and there will be considerable sparking at some of the brushes.

This can be tested by connecting a voltmeter across the terminals of the armature, or by means of a magnetic needle placed at a short distance from one of the pole pieces in such a position that it does not point to the north pole. If the field coils be improperly connected, the current due to the initial voltage will weaken the field magnetism and thus prevent the machine building up, and when the field circuit is closed, the voltmeter reading will be reduced, or the magnetic needle will be less strongly attracted.

How may it be ascertained which coil is reversed?

In all dynamos there should be an equal number of positive and negative poles, and in almost all of them the poles should be alternately positive and negative. Therefore, if a pocket compass be brought near the pole pieces, and it show that there are more poles of one kind than the other, the indication is that one

or more of the coils are reversed, and the improper sequence of alternation will determine which one is wrongly connected.

When a dynamo loses its residual magnetism, how can it be made to build up?

By temporarily magnetizing the field. To do this a current is passed through it from another dynamo, or from the cells of a small primary battery. Usually, this will set up sufficient initial magnetism to allow the machine to build up. The battery circuit should be broken before the machine has built up to full voltage.

FIG. 423.—Single pole circuit breaker (shown in off position). The laminated switch contact bridge C, when on, interconnects the two fixed contact plates, K,K; and the auxiliary carbon contacts C,C, break the circuit after the metal contacts C, and K,K, have separated, thus lessening the spark wear at the latter. The "breaker" is closed by hand, and is opened electro-magnetically when the current exceeds a predetermined strength. It may also be released by hand when necessary. Included in the main circuit between the terminals is a solenoid. When the breaker is put on, it is held in place by a catch, and if the current become too great, the solenoid acts with such force on its armature that the latter—through simple connecting mechanism—"trips" the catch, and allows the switch part to be pulled off by the helical spring S. The solenoid, etc., are contained in the box B, and the thumb nut at N, enables the apparatus to be adjusted within certain limits.

What is an automatic circuit breaker? Upon what does its action depend, and what advantage has it over a fuse?

An automatic circuit breaker is an apparatus for opening the circuit when an excessive amount of current passes through it.

A common form depends for its action upon the principle that a bar of iron will tend to balance itself in a solenoid. In this case the solenoid is composed of three or four turns of the entire current conductor; as the current increases the soft iron bar raises until it trips the spring actuated switch. Their advantage over a fuse is, that in case of a momentary overload they can be quickly thrown in again, whereas a fuse takes time to replace and, under certain conditions, is a dangerous operation.

What style winding is best adapted for a motor which is to run at a constant speed and carry a variable load?

The shunt winding is almost universally used for motors with variable load and using direct current.

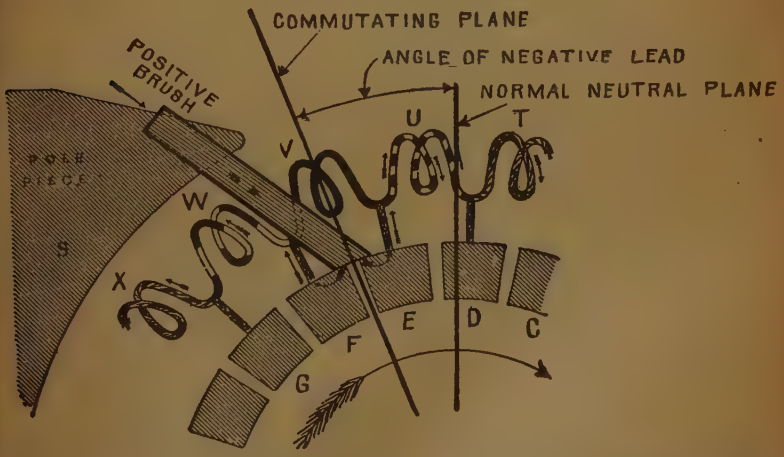


FIG. 424.—***Current commutation in a motor.*** Considering the coil W, which is ascending, current is flowing through it from the top brush, while it is itself the seat of an electromotive force that tends to stop or reverse its current. The condition for sparkless commutation requires that during the interval the coil is short circuited by the brush, the coil should be passing through a field that is not only sufficiently strong but one that tends to reverse the direction of its current. The coil is already in such a field, hence, commutation must take place *before* it passes out of this field. To accomplish this the brushes must be shifted backward, that is, given *negative lead*, to overcome sparking. In other words, the *commutating plane* must be shifted *back* of the neutral plane in a motor instead of being placed *in advance* as in a dynamo.

This type of motor gives a very nearly constant speed with a variable load, providing the voltage be kept constant.

Why is a starting box required in connection with a motor?

Explain also the automatic cut out and the reasons for attaching same.

A starting box is necessary in order to insert a resistance in the circuit, so that the current may be turned on gradually, otherwise one or more coils would burn out, as the total current would pass through them before the armature had a chance to start revolving. An automatic cut out is so arranged that should the exter-

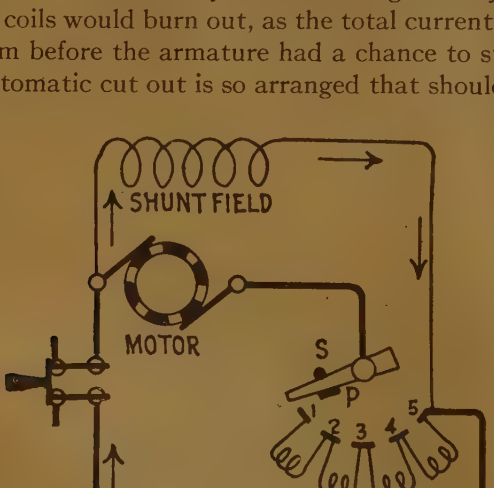


FIG. 425.—Speed regulation of shunt motor by variable resistance in the armature circuit.

nal circuit be broken, the box will automatically cut in its resistance and then open the armature circuit.

Should motors be run on independent circuits? Why?

Motors should be run on independent circuits, very often, however, they are cut in almost anywhere. The work of a motor with a variable load requires more or less current and if not on a separate circuit, unless the conductors are excessively large, will make the lights unsteady.

What broad rule should be observed on the score of personal safety when handling electrical conductors?

Be careful not to interpose any portion of the body where such will become a conductor of current.

A good rule for personal safety when working around electrical machines is to wear rubber gloves; use one hand only, as much as possible, and always stand on a dry or insulated spot.

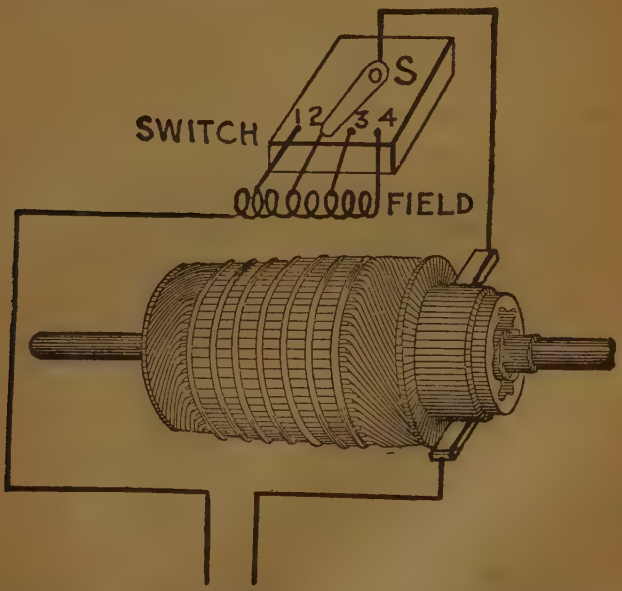


FIG. 426.—***Speed regulation*** of series motor by cutting out sections of the field winding. In this method the field winding is tapped at several points, dividing the coil into several sections and to the leads from these sections are connected a multi-point switch of the type that would be used on a rheostat. By moving the lever S, to the left or right, the current will flow through one or more sections of the field winding, thus decreasing or increasing the ampere turns and thereby providing means of regulation.

What general rules should be observed in making electrical connections?

The metallic surfaces should be perfectly clean and make good contact. They should also be mechanically strong enough to withstand any strain likely to be encountered.

What is a simple primary cell?

A combination of two dissimilar metal plates in an exciting fluid or *electrolyte* contained in a glass jar.

What is a "battery"?

A word often used incorrectly for a *cell;* it is a combination of two or more cells joined together so as to form one unit.

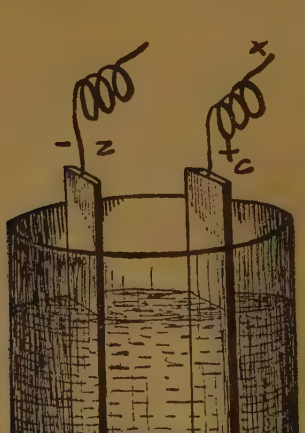


FIG. 427.—***A primary cell.*** Volta discovered that an electric pressure may be created between two dissimilar substances through chemical action set up by a solution in which they are immersed. This discovery led to the construction of the primary cell, long known as the *voltaic* cell. ***The cell consists*** essentially of two plates of different substances standing apart in a jar containing a solution which attacks one and not the other. By joining the outside terminals of the plates by a conducting wire, a current will flow from one to the other so long as the chemical action or *electrolysis* continues through the solution. The solution is known as the *electrolyte,* and the two plates are called the *elements.* This type of cell is called *primary* to distinguish it from the *secondary* or storage cell.

What is a "secondary" or "storage" cell?

One in which electrical energy may be stored.

Describe a secondary cell.

As usually constructed, it consists of a positive and negative set of lead plates immersed in an electrolyte of dilute sulphuric

acid. The proportion of acid to water is about one part acid to three and one-half parts of water.

In making the electrolyte, the acid should be added to the water—*never the reverse.*

Explain how a storage cell works.

In passing an electric current through a cell the plates undergo a chemical change; when this is complete the cell is said to be *charged.* A quantity of electricity has been stored in the cell,

FIG. 428.—The Exide storage cell. The positive and negative plates are separated by thin sheets of perforated hard rubber, placed on both sides of each positive plate. The electrolyte and plates are contained in a hard rubber jar.

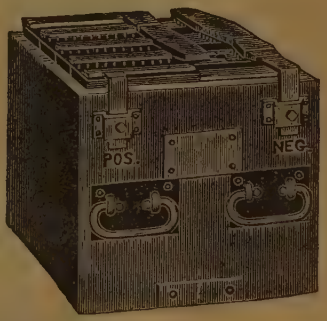


FIG. 429.—An Exide battery of five cells. The box which holds the cells is usually made of oak, properly reinforced, with the wood treated to render it acid proof. The terminals, as shown, consist of metal castings attached to the side of the box and plainly marked.

hence the name, *storage* cell. The cell after being charged will deliver a current in a reverse direction because during the discharge a reverse chemical action takes place which causes the plates to resume their original condition. When fully charged the positive plates are coated with peroxide of lead and are brown in color and the negative plates gray.

Describe the method of charging.

In charging, a direct current should be used—never an alternating one, care being taken to connect the positive wire to the positive terminal and the negative wire to the negative terminal. If connected in the reverse direction serious injury to the battery will result.

A storage battery should be charged at least once every two months whether it be used or not.

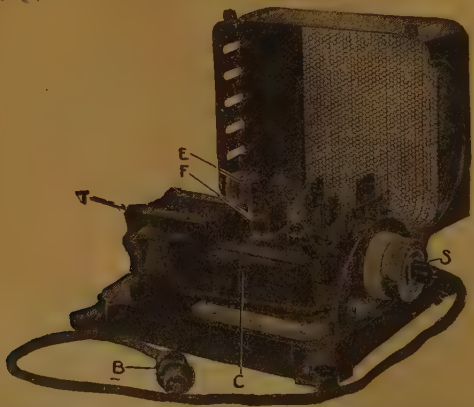


FIG. 430.—Edison Alternating Current rectifier; view with cover open showing parts. B, primary circuit cord; C, condenser; E, primary relay; F, secondary switch; S, alternating circuit switch; T, transformer.

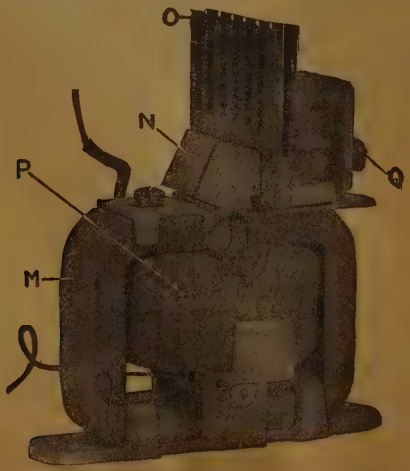


FIG. 430*a*.—Vibrating unit of Edison alternating current rectifier. M, permanent magnet N, carbon vibrating contact; O, comb radiator; P, primary circuit coil; Q, vibrator adjustment screw.

Operation of Edison Rectifier

The operation of the Edison rectifier may be explained as follows with the aid of figs. 430 to 431 (the parts being uniformly lettered in the figures): The primary circuit taken from the alternating current mains by the cord B, embraces the primary winding of the transformer T, a condenser C, and the coils P, of the vibrating units, fig. 430*a*.

The secondary circuit from the transformer embraces the massive carbon and copper contacts (N and O, fig. 431) which pass only the positive waves of the alternating current, for charging batteries or other duty.

An ammeter and rheostat may be placed in this charging circuit if the current is to be varied, or a fixed connection may be substituted on the base of the rectifier if it is to be used for the maximum duty of 8 or 16 amperes.

The vibrating unit (fig. 430*a*), which operates in a manner similar to the well known action of a polarized relay, includes a permanent magnet M; the coil in the primary circuit P; the vibrating armature of steel with removable carbon contact N; the stationary copper contact with comb top for heat radiation O, and the screw Q, for adjusting the amplitude of the armature vibration.

The vibrating armature of each unit is divided into two parts, which gives flexibility, affords increased current capacity and minimizes sparking, the two leads shown being connected together in one circuit.

A primary relay and a secondary switch (E and F, figs. 430 and 431), close their contacts when current is flowing.

Upon failure of the main alternating current line they operate to open the charging circuit. A storage battery is thus prevented discharging through the rectifier.

Upon resumption of the main alternating current, the rectifier starts automatically.

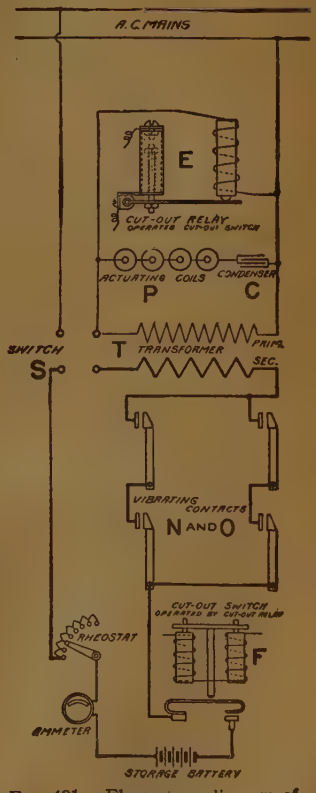


FIG. 431.—Elementary diagram of connections.

What is sulphation?

The formation of *sulphate of lead* on the plates of a storage cell in the form of a very hard grayish coating. This sulphate of lead is practically an insulator, hence, plates so affected are rendered useless unless it be removed.

Name some causes of sulphation.

Too strong or too hot electrolyte, over discharging, etc. The most common cause of sulphation is over discharging. A battery

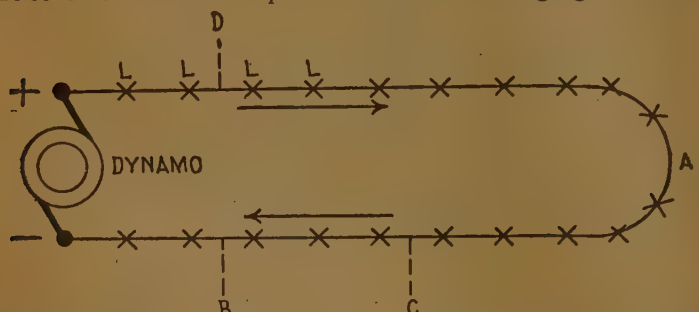


FIG. 432.—*Series system* of distribution. This is a constant current system, so called because the current remains practically constant. It is used chiefly for arc lighting. The current from the terminal of the dynamo passes through the lamps, L, L, L, L, one after the other and finally returns to the terminal. The current remains practically constant, but the voltage falls throughout the circuit in direct proportion to the resistance, and the difference in pressure between any two points in the circuit is equal to the current in amperes multiplied by the resistance in ohms included between them. Since the total voltage of the system is equal to the sum of the volts consumed in all of the lamps, it is high enough to be dangerous to personal safety. Thus, if the line be grounded at B, owing to defective insulation, the pressure of the circuit at that point will be zero, and therefore, a man standing on the ground could touch that point without receiving a shock, but if he should touch the line at the point C (assuming each lamp to cause a drop of 50 volts), he will receive a slight shock of 150 volts, as there are three lamps between the point C, and the ground connection B. Therefore, the danger of touching the circuit increases directly with the resistance between the point touched and the ground connection, so that if a man touch the circuit at the point D, he will receive a dangerous shock of $16 \times 50 = 800$ volts.

that is discharged to a low point and then allowed to lie around unused for a considerable time will be destroyed by sulphation or rendered practically useless.

What may be said of local sulphation?

Local *sulphation* is caused by small particles of the active materials, which have become dislodged from the plates, catching in the separators. The latter are used to prevent the plates

touching and forming a "bridge" between two plates and discharging them entirely.

Sediment, which gradually accumulates in the bottom of the jars, should be removed before it reaches the bottom of the plate.

How should sulphated plates be treated?

When the plates are sulphated the battery should be given a long, slow charge at one-quarter the normal charging rate, till the electrolyte shows the proper specific gravity and the voltage has attained its maximum. The terminals and top of the cell should be kept free from acid, which will cause corrosion.

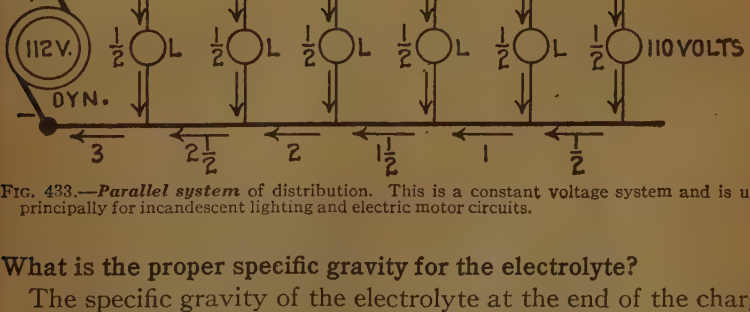


FIG. 433.—*Parallel system* of distribution. This is a constant voltage system and is used principally for incandescent lighting and electric motor circuits.

What is the proper specific gravity for the electrolyte?

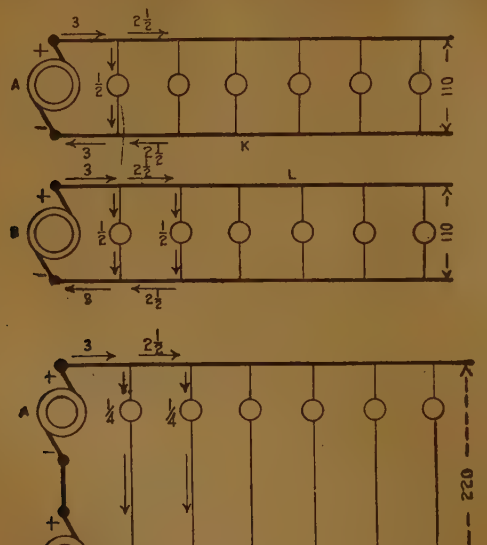
The specific gravity of the electrolyte at the end of the charge should be 1.3. The specific gravity should not be altered when the battery is fully charged.

Describe the Edison three wire system.

The Edison three wire system is a peculiar combination of series and parallel systems. Two lamps are placed in series with each other and the sets of two are in parallel with each other. A conductor, called the neutral, connects the point of junction of the lamps which are placed in series with each other and runs to the point of junction of the two dynamos (in series with each other) which supply the system.

What is the advantage of the Edison system?

It secures economy in the size of wire, from the fact that it permits the distribution at a higher pressure without any very



FIGS. 434 to 436.—***Evolution*** of the three wire system. ***In principle,*** two dynamos A and B, are shown supplying two independent incandescent lighting circuits, each circuit receiving 3 amperes of current at a pressure of 110 volts. It is evident that the dynamos could be connected with each other in series, and the lamps connected in series with two each, as shown in fig. 436, thus making the two wires K and L, of the two independent circuits unnecessary, as the pressure will be increased to 220 volts while the current will remain at 3 amperes, and each lamp will require ¼ ampere. The amount of copper saved will be 100 per cent., but this arrangement is open to the objection, that when one of the lamps is turned off, or burned out, its companion will also go out. This difficulty is avoided in the three wire system by running a third wire N, from the junction O, between the two dynamos, as shown in fig. 437, thus providing a supply or return conductor to any one of the lamps, and permitting any number of lamps to be disconnected without affecting those which remain. If the system be exactly balanced, no current will flow through the wire N, because the pressure *toward* the — terminal of the dynamo A, will be equal to the pressure *from* the + terminal of dynamo B, thus neutralizing the pressure in the wire. For this reason the middle wire of a three wire system is called the *neutral wire,* and is usually indicated by the symbol O or + the latter meaning that it is positive to the first wire and negative to the second. If the system be unbalanced, a current will flow through the neutral wire, to or from the dynamos, according to the preponderance of lamps in the upper or lower sets. When the number in the lower set is the greater, the current in the neutral wire will flow *from* the dynamos, and *toward* the dynamos under the reverse condition.

serious disadvantages; for example, the distribution on the feeders and mains is essentially at 220 volts, while the pressure on the branch circuits and the lamps is only 110 volts.

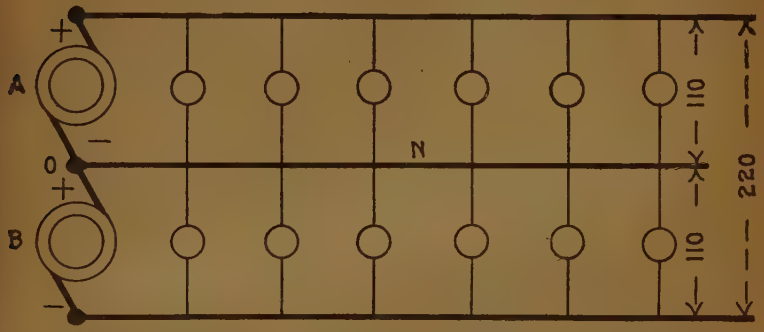


FIG. 437.—Balanced three wire system. The middle conductor, known as the *neutral wire*, keeps the system balanced in case of unequal loading, that is, a current will flow through it, to or from the dynamos, according to the preponderance of lamps on the one side or the other.

FIGS. 438 and 439.—D & W fuse indicator. The operation is illustrated in the figures which show appearance of the label before the blowing of the fuse, fig. 438, and the same fuse blown, as indicated by the appearance of the black spot within the circle fig. 439.

What is a fuse, and why and where is it used?

A fuse consists of a piece of metal, usually some alloy of lead which will melt at a fairly low temperature, soldered to copper terminals. It is intended to melt whenever the current passing through it exceeds the safe carrying capacity of the wire which the fuse is designed to protect. Fuses are placed at all points of a circuit where there is a change made in the size of the wires.

CHAPTER THIRTY-ONE

ELECTRIC SHIP PROPULSION

Although the steam turbine is extensively used for propelling vessels of various kinds it is subject to certain limitations which detract from its value, especially for heavy marine work such as battleship propulsion.

For instance, while the turbine operates at its highest efficiency when driven at a very high rate of speed, the screw propeller of the ship attains its maximum efficiency when turning at a speed relatively very low—about 160 revolutions per minute. This means the introduction of gearing or some other mechanism to reduce the speed of the turbine to that best adapted to the propeller.

Furthermore, since the turbine runs inherently in one direction only, means must be provided for reversing the propeller, either by providing a reverse gear, or by installing on the turbine shaft an extra set of vane for backing. The latter method is the one generally used, although the backing turbine is driven idly by the ahead turbine, thus increasing the cost weight and space of the unit while decreasing its mechanical efficiency.

Flexibility of control in both backward and forward movements is of the highest importance in the fighting ship, and for this reason the builders have been forced to employ a driving mechanism embodying every possible feature of advantage regardless of the cost of installation and subsequent operation.

Another essential in the propulsion of a battleship is that it

shall be capable of cruising day in and day out at about three-quarter speed and at the same time be able to make a sudden, though perhaps long continued spurt at its maximum speed.

The turbine is essentially a one speed machine and its ideal operating speed is a high one. In order, therefore, that it be made capable of attaining the higher speed, it must be operated for the greater part of the time (while cruising) at comparatively low efficiency.

The object of the electric drive is to overcome the inherent

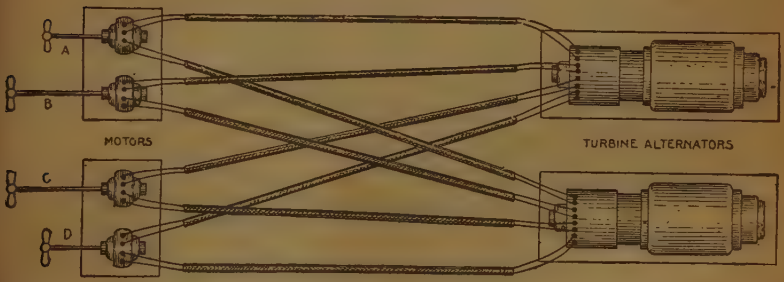


FIG. 440.—Elementary diagram illustrating the essentials of electric ship propulsion. Two turbine alternator units are shown on the right which are wired for various connections with the motors; the latter operate the propellers A, B, C, and D.

defects or limitations of the turbine, that is to say, its function is similar to the so called "transmission" of an automobile in that it gives flexibility of control and permits the turbine to run at its most economical speed.

Various combinations of machinery for electric propulsion have been worked out, being suggested by plans and principles of proved appropriateness which have been employed in electric power plants on land. These various systems have been proposed by Emmet, Mavor, Durtnall, Hobart, Day, and others. The problem has been to so combine generating units with motors that the maximum efficiency of the turbine could be obtained under all working conditions of the vessel, as in manœuvring,

cruising at low or moderate speed, and when being driven at high speed.

An examination of the simple diagram, fig. 440, will serve to make clear the plan of the driving mechanism. The generating plant is composed of two independent turbine alternators, each of which is capable of delivering one-half of the total power necessary to run the ship at maximum speed. The driving motors are of the three phase variety and each motor is equipped with two sets of pole piece—one of twenty-four poles and the

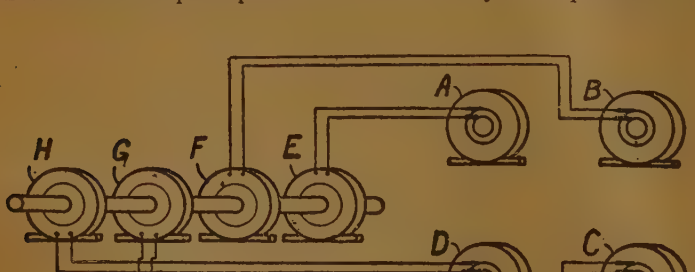


FIG. 441.—***Hobart's alter-cycle control*** of induction motors for electric ship propulsion. There are four motors E, F, G and H, wound respectively for 24, 36, 48, and 72 poles. The maximum speed of the propeller shaft is 100 *r.p.m.* with full power of all the motors. To run the motors at 100 *r.p.m.* requires frequencies of 20 cycles for the 24 pole motor, 30, for the 36 pole motor, 40, for the 48 pole motor, and 60, for the 72 pole motor. Thus to obtain equal *r.p.m.* the frequencies of the four alternators A,B,C,D, are respectively made 20, 30, 40, and 60. To obtain these frequencies when the alternators are down say to 600 *r.p.m.* requires respectively 4, 6, 8, and 12 poles for the alternators A,B,C. and D. To drive the ship at two-thirds speed, motors F and H, are connected to alternators A and C, which provide respectively ⅔ of the frequencies of B and D, to which F and H, were connected for full speed running. Since for the lower speed only about 3/10 as much power is required as for top speed, alternators B and D, and motor E and G, are shut down. For half speed a single motor is sufficient; this can be provided by operating motor H, from alternator B, or G, from A. One-third speed is obtained by operating H, from A.

other of thirty-six. By operating the motors on one or the other set of pole, the speed is changed without impairing the efficiency in any way. The plan of operation is to drive the motors at the lower speed for cruising with only one turbine alternator in operation, while for the greater speed the two alternators would be operated in tandem with the motors arranged to run at their

maximum speed. Thus it will be seen that when cruising, the one alternator is running at its full efficiency as are also the motors, while the second alternator is idle. Likewise, when full speed is required, the second alternator is started and run also at its peak of efficiency.

The following description of the machinery for electric propulsion in the new battleship *California* will illustrate more in detail the features of electric propulsion:

The outfit consists essentially of a port and a starboard unit, each consisting

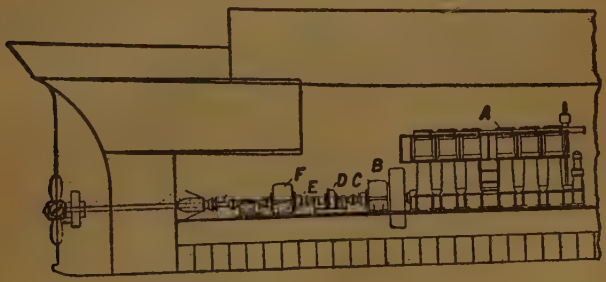


FIG. 442.—The *Menlees system* of propelling ships by gas engines. In the figure A. is a six cylinder gas engine coupled to a dynamo B. The shaft C. of the dynamo and engine is adapted to be connected by a clutch D. with the shaft E. of the electric motor F, which is connected with the propeller shaft. ***In operation,*** at all ahead ship speeds direct driving may be employed, but, for speeds less than half, the electrical transmission may be used, the motor F, receiving electrical energy from the dynamo B. The drive may also be employed for reversing the astern speed by not greater than half the full ahead speed, suitable switches and gear being provided.

of a turbine driven, two pole, quarter phase alternator and two double squirrel cage induction motors. Direct current field excitation, at 230 volts, for the alternator, is supplied from a turbine driven alternator in the engine room, or, if desired, is obtained from the ship's mains.

Conversely, the two exciters may be used in port to supply power to the ship's mains, and thus form two valuable additions to the vessel's power plant.

The motors have two possible arrangements of pole, the change from 36 poles to 24 poles being accomplished by simply throwing a switch. There is one motor in a separate compartment for each of the four shafts.

For 21 knots both turbine units are run and the four motors are used in their 24 pole rig (low gear). This reduces the full turbine speed of 2,000 *r.p.m.* to 165 *r.p.m.* of motor or propeller.

At cruising speeds one turbine is connected to the four motors in their 3 pole rig (high gear). Thus either turbine at 2,000 *r.p.m.* drives four motor at 110 *r.p.m.* The other turbine is meanwhile not in use.

When the motors are not connected, the turbine runs at no load and th motors stand idle. If connected to one alternator, all the motors turn (if i the same pole setting) at the same speed, although, if it be desired to bac the port, and at the same time stop or go ahead on the starboard motors, thi is possible. In other words, when in cruising rig the ship can be quickl

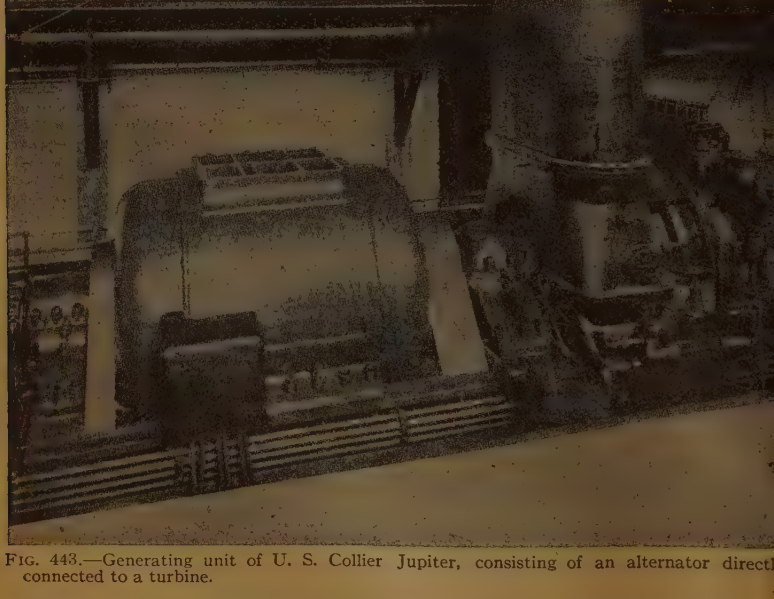


FIG. 443.—Generating unit of U. S. Collier Jupiter, consisting of an alternator direct connected to a turbine.

started, stopped, or turned by various combinations of the four motors drive by one turbine, and power for 19 knots is available.

Speed control with either one or two alternators running is entirely b turbine throttle or on the so called "variable-frequency" principle.

It is at once evident that the electricity between turbine shaft and propelle shaft simply performs the same function that a clutch and gear box do on a automobile. The electric machinery simply makes it possible to reverse th propeller shafts and keep the turbine running in the same direction, and als gives two gear ratios between turbine shaft and propeller shafts.

The electric rig does not have a "direct drive," as does an automobil because this is just what is not wanted in a ship. On the other hand, th

electric rig gives two speed ratios ahead and two backing, while the automobile gives usually two ahead (besides "direct") and one backing. Being in any gear setting with either ship or automobile, *to go faster, speed up the engine; to slow, slow the engine.* Without "shifting gear" *speed changes can be made in no other way.* In the automobile the clutch can at any time be thrown out and leave the engine running; with the ship, the motors may be disconnected electrically and leave the turbine running.

Between the exciter and the alternator there are, besides the usual protective circuit breakers, one switch and one rheostat. As has been said, the ship's circuit can be used for supplying excitation for the alternators, or in port the exciters, which are of about 300 kw. capacity, can be used for supplying power to the ship's mains.

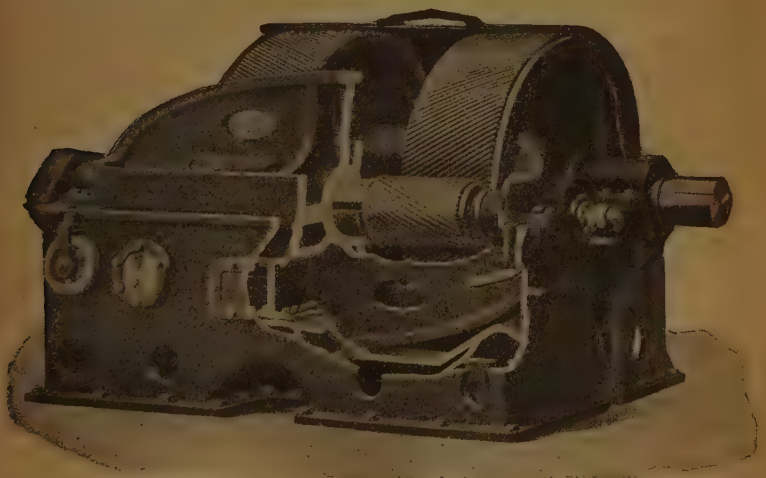


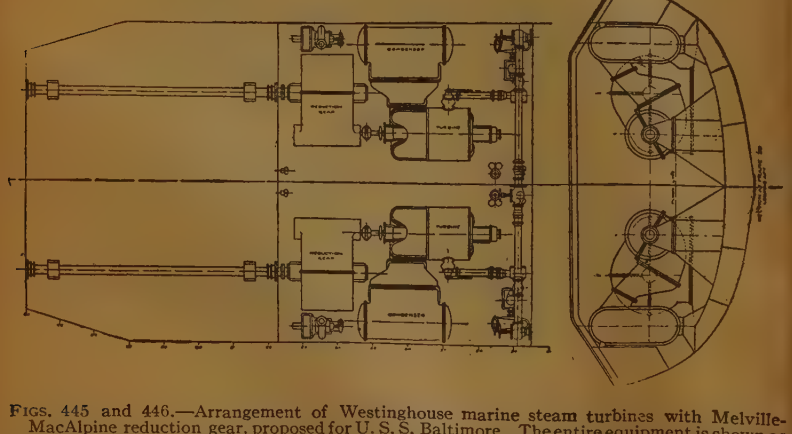
FIG. 444.—View of 6,000 horse power Melville-MacAlpine ***speed reduction gear*** with case broken away showing construction. It is a double helica lspur gear, designed with involute teeth, and a transmission capacity of 6,000 horse power at a pinion speed of 1,500 *r.p.m.* The pinions have 35 teeth, the spur wheels 176 teeth. The 176th tooth constitutes a hunting cog and equalizes the wear. The pitch circle diameters are 14 ins. and 70 ins. respectively. The reduction ratio is thus practically 5 to 1, hence the power is delivered from the gear at a speed of only 300 *r.p.m.* The pitch line speed is 5,500 ft. per minute and the design is based on a limiting pressure of 450 lbs. per inch of tooth contact. Provision is made for the liberal use of lubricating and machine oil. Rear-Admiral Melville, writing in Proc. Inst. Civil Engineer, Feb. 1910, states as follows: "A full power test of 6,500 horse power was carried out for a period of 40 hours from 2:30 P. M. on Oct. 16, 1909, till 6:30 A. M. Oct. 18. At the close of this test the gear was found to be in excellent condition and without any sign of wear." This established without question the fact that gearing could be made to transmit such large powers continuously at high speed.

The four main leads from the armature of, say, the port alternator go through a four pole switch to the port bus bar. As this switch is opened only when no power is on the system, it is of the usual knife type. The two port

motors are connected in parallel and then through either one of two electrically actuated main oil switches to the bus bars. When closed, one of these oil switches connects the pair of motor for "ahead" operation; and when closed, the other switch connects the motors for "astern" operation. Only one of these switches can be closed at a time, and the closed switch is locked so that it cannot be opened until after the alternator field switch is open. This last provision makes it impossible to break the main circuit until the current in it practically ceases to flow.

In each motor circuit there is a four pole, double throw switch. One closed position of this switch connects the motor for 36 poles, the other closed position for 24 poles. As the pole changing switches are never used with power on the circuit, they are simply knife switches.

When in cruising rig with all four motors driven by one turbine unit, the port and starboard bus bars are connected together. At all other times the port and starboard sides of the ship are not electrically connected.



FIGS. 445 and 446.—Arrangement of Westinghouse marine steam turbines with Melville-MacAlpine reduction gear, proposed for U. S. S. Baltimore. The entire equipment is shown as if installed in one of the two engine rooms occupied by the reciprocating engines with which this vessel was actually fitted. Since the gearing is of 98½ per cent. or conservatively 98% efficiency, the output for a group of turbine such as would drive the Mauretania at a speed of 25 knots would be 60,500 ÷ .98=62,000 horse power, requiring an estimated weight of 260 tons. The weight of gearing for a ship of the Mauretania's displacement and speed would amount to some 300 tons in place of a weight of some 1,100 tons of machinery which would be saved. The turbines of the Mauretania are rated at 70,000 shaft horse power. Even the comparatively low speed at which these turbines run is too high for maximum propeller efficiency. It is hardly possible that the propeller efficiency exceeds 55 per cent., which means that the actual effective propelling power is only about 38,500 horse power. At a lower speed well within the capabilities of the reduction gear, a propeller could be made that would have an efficiency of not less than 65 per cent. With this improved efficiency, the shaft horse power required for the same effective propelling power would be somewhat less than 57,000, a saving of almost 15 per cent. With the turbine and propeller direct connected so that both revolve at the same speed, not only is it necessary to sacrifice the efficiency of the propeller, but also the efficiency of the turbines.

CHAPTER THIRTY-TWO

GAS ENGINES

The term "gas engine" is usually used to designate the internal combustion engine without regard to whether it operates with gas or liquid fuel. The purpose of all engines is to convert ***the heat*** generated by the combustion of the fuel ***into work.*** Existing engines may be divided into two classes according as the combustion takes place outside or inside the working cylinder.

In the first named class, the heat of combustion is transmitted by conduction externally to a working substance or medium, which carries the heat into the cylinder and there is transformed into work. The most common example of this class is the steam engine; another example, though in limited use, is the hot air engine.

In the second class, the fuel is introduced into the cylinder in the form of an explosive mixture, and there is ignited; the heat generated by the combustion is transformed into work, acting directly on the piston—hence the name, "internal combustion engine."

Gas or internal combustion engines may be classified in several ways, as

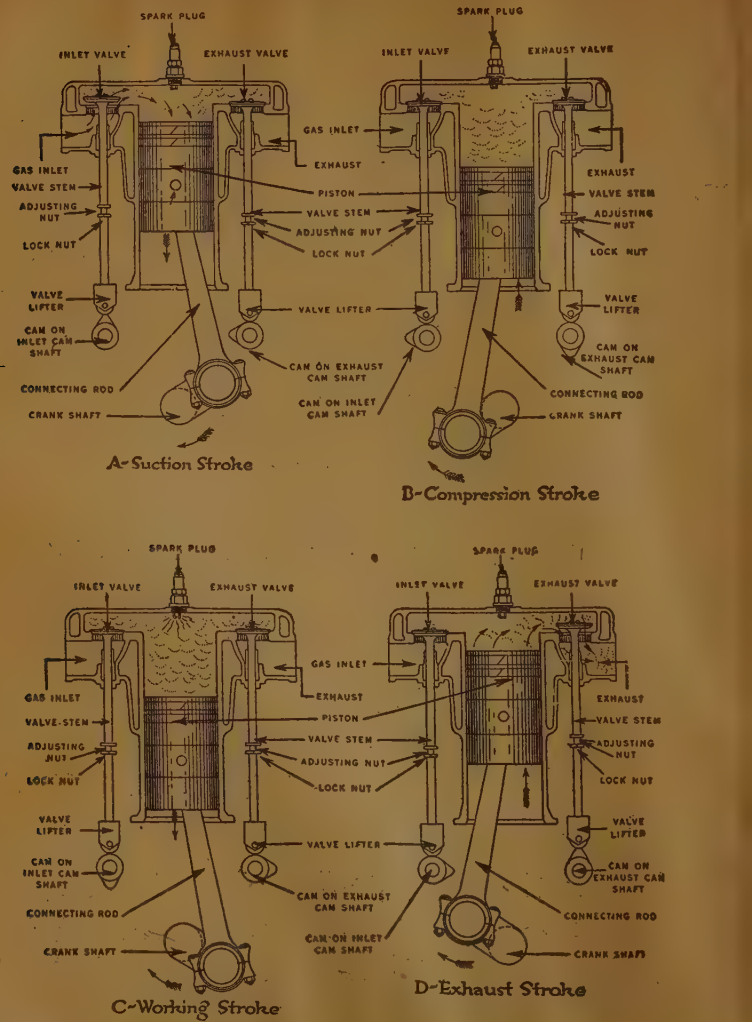
1. With respect to the fuel, as

   a. Gasoline;
   b. Kerosene;
   c. Oil.

2. With respect to the working cycle, as

   a. Four stroke cycle;

   b. Two cycle. { two port / three port



FIGS. 447 to 450.—Diagrams showing ***operation of the valve gear*** for the four strokes of a four cycle engine. Two revolutions or four strokes of the engine are required for the cycle. During the first stroke, the "charge" is drawn into the cylinder, which is compressed during the second stroke, burned during the third, and exhausted during the fourth stroke.

3. With respect to the degree of compression, as

a. Low;
b. Medium;
c. High.

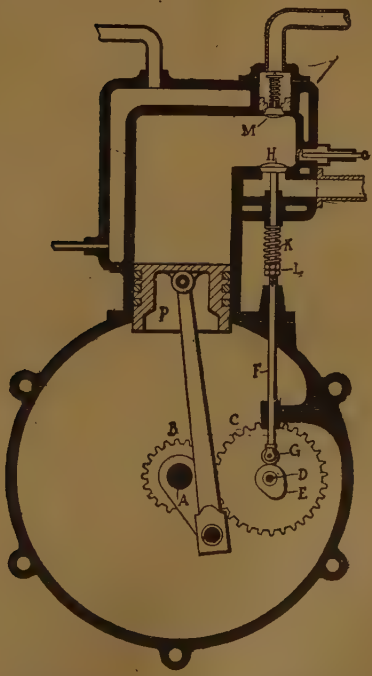
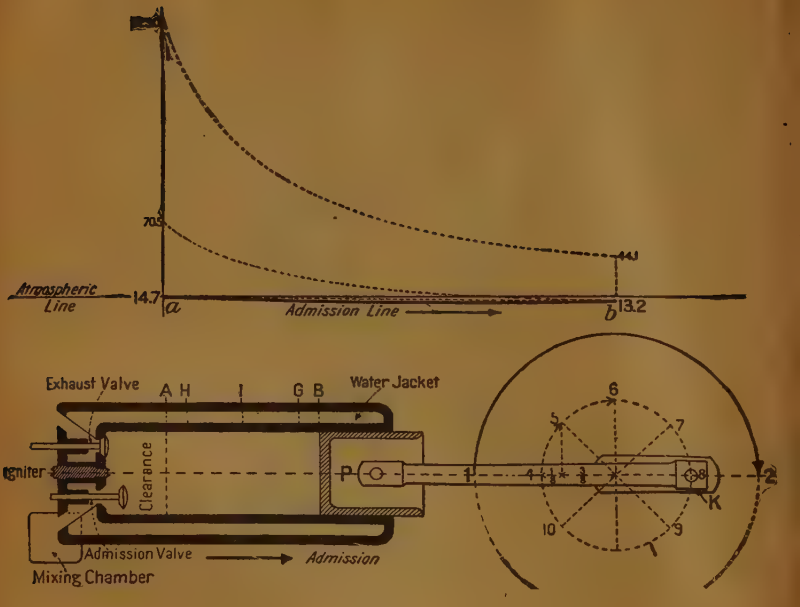


FIG. 451.—Sectional view of a four cycle gas engine with ***automatic admission valve.*** This valve M, is automatically opened by the suction of the engine. The exhaust valve is mechanically opened when the cam E, revolves and raises the roller G, which is on the bottom of the lifter rod F. The rod F, extends upward and rests against the bottom of the stem of the valve, H, although between the two or at their point of contact are nut and locknut L, for lengthening or shortening the lifter F, and so to vary the time of opening or closing of the valve. The spring K, is compressed or squeezed together when the valve is opened, and immediately the cam E, travels around and allows the roller G, to fall; this spring exerts its pressure and closes the valve.

4. With respect to the introduction of the fuel, as

a. By suction;
b. By injection.



FIGS. 452 and 453.—*The four stroke cycle:* ***charging stroke.*** During this stroke the piston moves from A, to B, the crank from 1, to 2, and the indicator pencil traces the admission line *ab*. Usually the fresh charge is admitted at atmospheric pressure and temperature, but while it is being drawn in, it becomes heated by the burnt gases left over from the previous combustion, and also by contact with the hot walls of the cylinder. The temperature of the burnt gases may be as high as 1,000° Fahr., but it is impossible to determine accurately just how much heat is thus added to the fresh charge; therefore, the initial compression temperature becomes a matter of assumption in gas engine calculations. Usually, and in the absence of a temperature diagram, the initial compression temperature is assumed to be slightly above that of the issuing jacket water and ranges from 150° to 200° Fahr. It will be understood in this connection, that in the case of a gas engine, the jacket is used for an entirely different purpose, to that which is the case with a steam engine. In the latter, the temperature of the working substance is comparatively low, and requires to be kept constant. This is accomplished by placing a jacket of non-conducting material around the cylinder to keep in the heat; while in the case of the former, the temperatures occurring within the cylinder, through the combustion of the highly inflammable gases therein, are so high, that a jacket of circulating water is placed around the cylinder for the purpose of carrying off a portion of the heat. Under these circumstances, an initial compression temperature of 170° Fahr., represents a fair average for an ordinary or non-scavenging engine, and 150° Fahr., that of a scavenging engine. Another condition which affects the charge during admission is the reduction of pressure due to wire drawing. This causes the pressure to drop below that of the atmosphere, so that the admission line usually forms a loop below the atmospheric line. ***In actual practice,*** the drop of pressure due to this cause ranges from ¼ to 1¾ pounds, about 1½ being a fair average. This gives a normal initial compression pressure of 13.2 pounds per square inch.

5. With respect to the ignition of the fuel, as

a. By external means;
b. By the heat of compression.

The Cycle of a Gas Engine.—The term "cycle," as applied to an engine, is defined as a **series of events which are repeated in regular order, constituting the principle of operation.** These several events comprise the transformations which take place in the working medium, or, with reference to the gas engine, the distribution and behavior of the fuel mixture in passing through the engine.

The gas engine derives its energy from the heat, generated by the combustion within its cylinder, of a **mixture of fuel** in the form of a gas or spray mingled with air in proper proportion to form an explosive mixture.

The mixture is admitted to the engine intermittently, and the amount supplied at each admission is known as the **charge.**

The combustion of each charge takes place under pressure attained by **compression**—a result of the inward movement of the piston after the charge is admitted and all valves closed.

The effect produced by igniting the mixture after compression is commonly called an **explosion,** which is simply a quick burning or rapid combustion of the mixture.

This sudden explosion causes a high degree of heat within the combustion chamber, resulting in considerable initial pressure, and gives to the piston an **impulse,** which decreases in intensity while the piston advances to make the **power stroke,** by reason of the expansion of the gases.

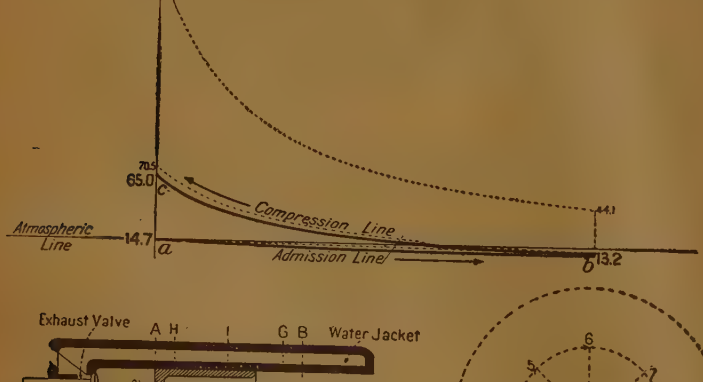
The products of combustion are finally **exhausted** from the cylinder.

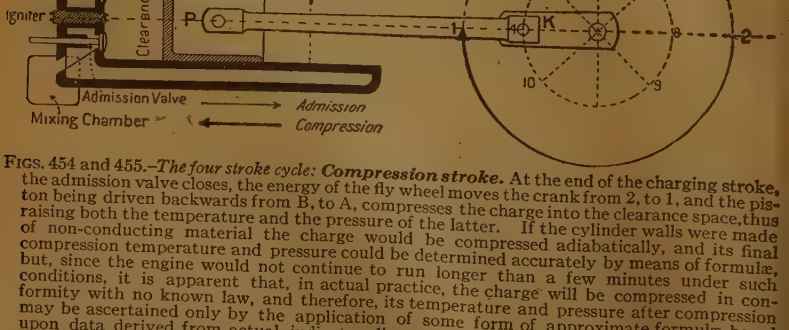
Expressed briefly, the cycle of a gas engine embraces: 1, the admission of the charge into the cylinder; 2, its compression; 3, ignition; 4, combustion; 5, expansion therein; and 6, the subsequent exhaust of the products of combustion.

In the operation of a gas engine, the number of strokes required to complete the cycle varies with the type of engine. The cycle is usually extended through four strokes, although in the small sizes it is usually completed in two strokes. Engines of these types are known respectively as **four cycle** and **two cycle.***

*NOTE.—These terms have been criticised by some as incorrect; they are conveniently and properly applied to the gas engine when considered as abbreviations for four stroke cycle, and two stroke cycle.

The Four Cycle Engine.—This engine, although more bulky than the two cycle engine, and requiring twice the number of cylinders for equal turning effect, is almost universally used except in small sizes; it has some advantages over the two cycle engine, which have more than offset its undesirable





FIGS. 454 and 455.—*The four stroke cycle:* ***Compression stroke.*** At the end of the charging stroke, the admission valve closes, the energy of the fly wheel moves the crank from 2, to 1, and the piston being driven backwards from B, to A, compresses the charge into the clearance space, thus raising both the temperature and the pressure of the latter. If the cylinder walls were made of non-conducting material the charge would be compressed adiabatically, and its final compression temperature and pressure could be determined accurately by means of formulæ, but, since the engine would not continue to run longer than a few minutes under such conditions, it is apparent that, in actual practice, the charge will be compressed in conformity with no known law, and therefore, its temperature and pressure after compression may be ascertained only by the application of some form of approximate formulæ based upon data derived from actual indicator diagrams. A careful study of a large number of such diagrams indicates the following named properties and conditions, considered in connection with the action of the machine, as the principal factors which affect the final compression temperature and pressure of the charge: 1. The dilution of the charge or the proportion of gas to air. 2. The quantity and character of the burnt gases remaining in the clearance after exhaust. 3. The specific heat of the charge. 4. The ratio of compression. 5. The piston speed. 6. The temperature of the jacket water. The combined effect of these factors may cause the indicator pencil or trace the compression line *bc*, either above or below the calculated normal. In the present case it lies below the normal, the indicated final compression pressure being 65 pounds, corresponding to a calculated final compression temperature of about 400° Fahr.

features, and caused it to come into general favor. Among the advantages which may be mentioned are: efficiency, flexibility, adequate admission at high speeds, higher degree of expansion, and more efficient exhaust.

Name the four strokes comprising the working cycle of the four cycle gas engine.

1. The suction; 2, compression; 3, power; and 4, exhaust strokes.

Describe what takes place during each stroke.

During the suction stroke the piston moves outward and draws in a charge of the fuel mixture. The following inward stroke compress the charge into the combustion chamber; just before the end of this stroke the charge is ignited, which causes a rapid rise of pressure, and subsequent expansion of the products of combustion during the next, or power stroke. The expanded gases are expelled from the cylinder during the return, or exhaust stroke of the cylinder.

How often does the piston receive an impulse?

Once in every two revolutions.

Describe the action of the valves during the cycle.

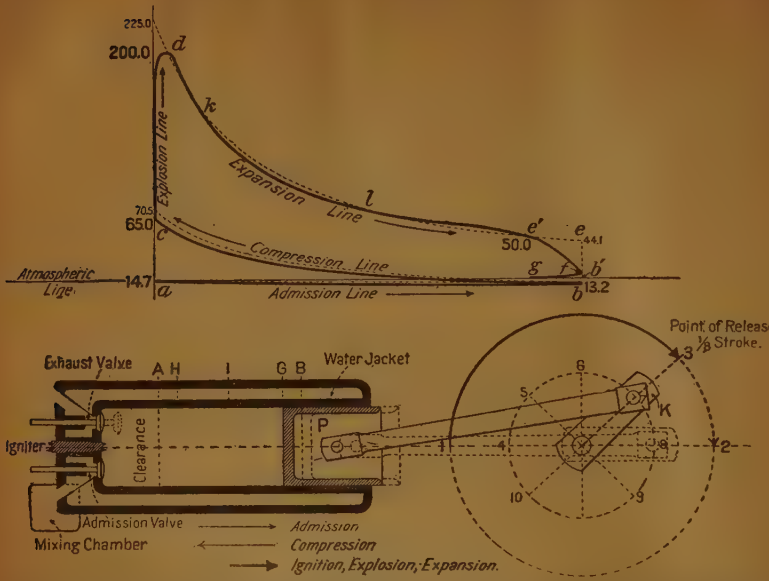
During admission, the inlet valve remains open, and the exhaust closed; during the compression and power strokes, both valves remain closed; exhaust takes place with the inlet valve closed, and exhaust open.

When does ignition take place?

At a variable time, near the end of the compression stroke depending upon the speed and load.

Why before the end of the compression stroke?

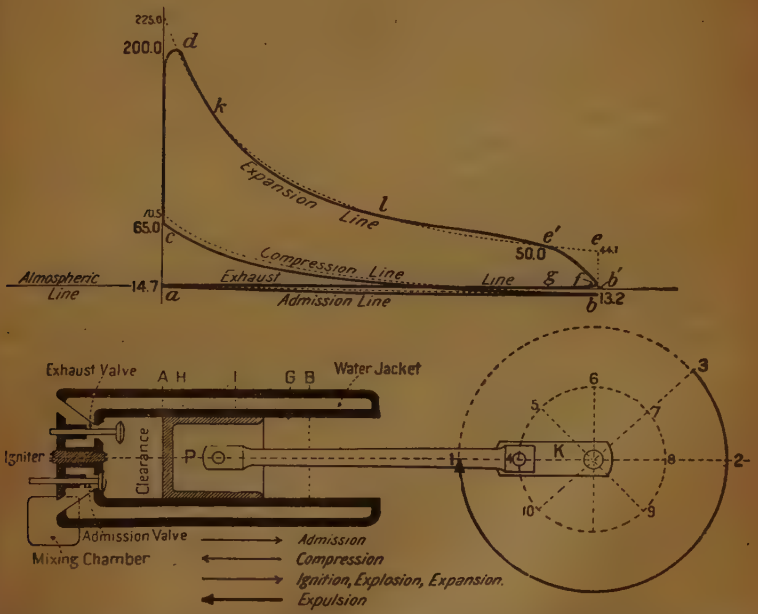
So there will be time for the pressure due to combustion to build up and thus secure a high initial pressure at the beginning of the power stroke.



FIGS. 456 and 457.—***The cycle of a gas engine; Power Stroke.*** Near the end of the compression stroke, the charge is ignited, and the heat evolved by the combustion of the fuel gas increases the temperature and pressure of the charge in the cylinder. Since these phenomena occur while the crank is passing over its inner dead center 4, and through the arc of the crank circle from 4, to 5, during which the forward movement of the piston is very slow, the volume of the charge is kept practically constant while its temperature and pressure are rapidly increased, and cause the indicator pencil to trace the explosion line *cd*. The position of the point *d*, which corresponds to the maximum pressure of the cycle or the initial expansion pressure, depends upon the following conditions: 1. The explosion temperature of the charge due to the calorific value of the fuel gas and the rate of inflammation of the mixture. 2. The point of ignition, or the point in the revolution of the crank relatively to its inner dead center 4, at which the charge is ignited. 3. The piston speed, or the number of revolutions of the crank per minute. In the present case, the position of the point *d*, indicates that the combustion was practically instantaneous or explosive, the maximum pressure of the cycle or the initial expansion pressure of 200 pounds corresponding to an initial expansion temperature of 2,195° Fahr., being attained shortly after the crank had passed over its inner dead center, thus preventing the delivery of a dead blow on the piston. From the point *d*, the charge expands, driving the piston forward from A, toward B, at the expense of its own internal energy, the crank in the meantime revolving from 1, towards 3. If the cylinder walls were non-conducting, the expansion would be adiabatic, but in actual practice, a variety of conditions and circumstances causes the actual expansion line traced by the indicator pencil to deviate not only from the path of an adiabatic line, but also from that of any calculated normal. The probable conditions which cause these deviations may be briefly stated as follows: 1. During the passage of the crank from 4, to 5, the maximum pressure remains constant, and the movement of the piston from A, to H, causes the pencil to trace the actual line across the normal near the point *d*. 2. During the movement of the piston from H, to G, the variations in the speed of the piston occasion irregularities in the rate of expansion or increase of volume, which, in connection with the effect due to afterburning, cause the pencil to trace a line of varying pressures and temperatures crossing and recrossing the normal at different points such as *k*, and *l*. The theoretical consideration of these various causes and effects involves the analysis of a series of very complex problems of a more or less hypothetical character. Such analyses are unnecessary, however, as the indicator diagram affords the means by which the probable causes of actual effects may be determined with sufficient accuracy to serve the purposes of gas engine design and operation.

What means are provided to keep the engine in motion during the three non-power strokes of the cycle?

A heavy fly wheel; this receives sufficient momentum during the power stroke to keep the engine going at approximately uniform speed during the period between impulses.



FIGS. 458 and 459.—*The cycle of a gas engine:* ***Exhaust stroke.*** The backward movement of the piston from B, to A, expels the burnt gases from all parts of the cylinder except the clearance. During this operation, the indicator pencil will trace a line *ga*, which will either coincide with, or lie above, the atmospheric line according to the following conditions: 1. If the exhaust valve be properly set and wire drawing be not present, the pressure will be reduced to that of the atmosphere when the piston reaches the point *g*, on its return stroke, and the exhaust line traced by the pencil will coincide with the atmospheric line. 2. If the exhaust valve be set so as to release at too high a pressure, and wire drawing be present, the pencil will trace a line which will lie above the atmospheric line at a distance corresponding to the resulting back pressure.

What objection is there to a single cylinder engine?

The weight and size of the fly wheel must be considerable on account of the prolonged pauses between impulses; by reason

also of the large size piston necessary, there is considerable vibration.

How is this overcome?

By the use of several small cylinders in place of a single one of large size.

Explain the action of a multi-cylinder engine in overcoming the objection to a single cylinder.

The heavy impulse of the single cylinder engine may be divided

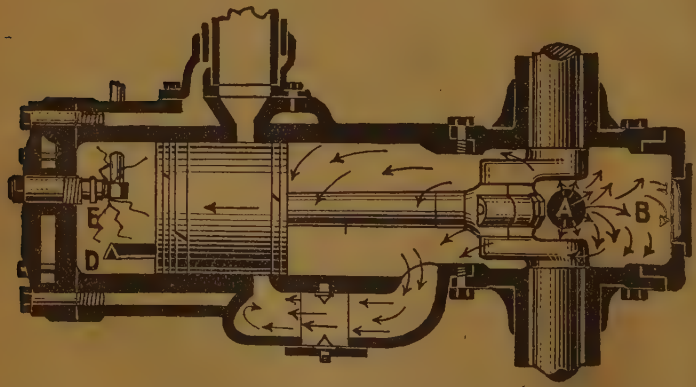


FIG. 460.—The two cycle engine: first stroke. The inward stroke of the piston induces a charge of the mixture at A, into the crank case B, and compresses the previously admitted charge into the cylinder D; the subsequent ignition takes place at E.

into several small impulses by working a number of small cylinders from one shaft. In order to reduce vibration, and secure a better turning effect, the cranks are so placed that the several impulses occur at different times. A small fly wheel then suffices to secure approximately uniform rotation.

The Two Cycle Engine.—This engine is built usually in small sizes, the essential difference between it and the four cycle type is that the four operations of admission, compression, impulse, and exhaust, comprising the working cycle, are performed

in one revolution instead of two. There is, then, one impulse for each revolution. From this, it follows that the weight is much less than that required for the four cycle engine. The necessary mechanical features for two cycle operation are as follows:

1. An enclosed crank case fitted with a valve arranged to open and admit fuel mixture at the front of the piston, on the inward stroke.

2. Inlet and exhaust ports located near the extreme outward

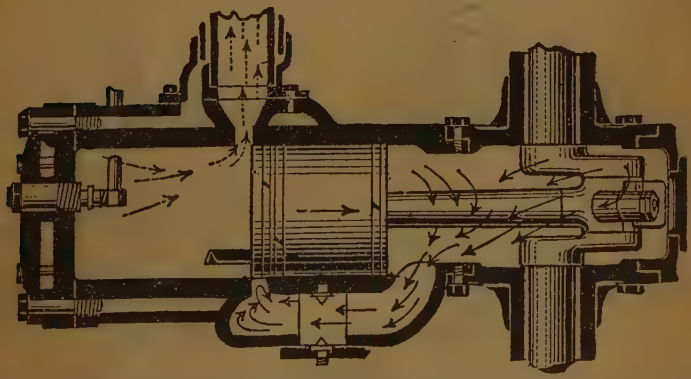


FIG. 461.—*The two cycle engine:* ***first part of second stroke.*** The outward stroke of the piston uncovers the exhaust port, thus releasing the burnt gases in the cylinder, and simultaneously compressing the previously admitted charge in the crank case.

position of the piston, so that they will be uncovered during the outward stroke.

3. A by-pass tube connecting the interior of the cylinder with the crank case, so as to admit the charge at the proper point in the cycle.

In the operation of a two cycle engine, what occurs during the first stroke?

The piston moves inward and draws in a charge of the explosive mixture into the enclosed crank case; during this operation the

charge previously admitted to the cylinder is compressed and ignited as the piston nears the end of the stroke, as shown in fig. 460.

What occurs during the second stroke?

The pressure caused by the explosion of the charge drives the piston outward, and slightly compresses the mixture drawn into the crank case during the previous stroke, as in fig. 461. Near the end of this stroke the piston uncovers the exhaust port and the burnt gases are exhausted. During the remainder of the stroke

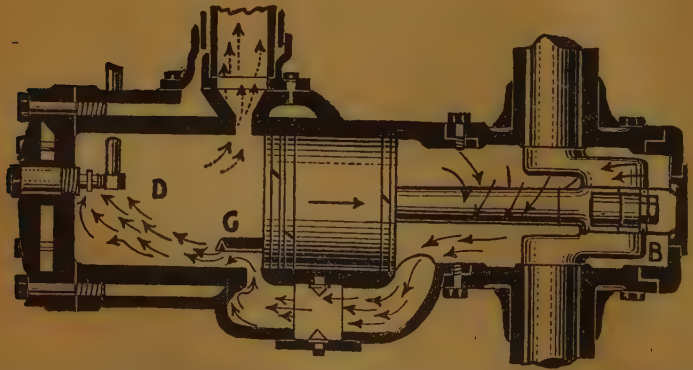


FIG. 462.—The two cycle engine; end of the second or outward stroke. The gases compressed in the crank case are admitted to the cylinder space D, through the open inlet port, and sometimes past the screen or deflector C. The passage between the cylinder and the crank case is controlled by a butter-fly valve, which here, as in figs. 8 and 9, is shown open.

the piston uncovers the admission port, as in fig. 462, and the new charge, previously compressed in the crank case, is admitted to the cylinder, being deflected upward to the head end of the cylinder by a screen or "deflector plate" set in the end of the piston.

The "inrush" of the new charge helps materially to clear the cylinder of the burnt gases from the previous charge. The object of the deflector plate is to prevent the entering charge passing out through the exhaust in place of the burnt gases.

What is the advantage of the three port two cycle engine?

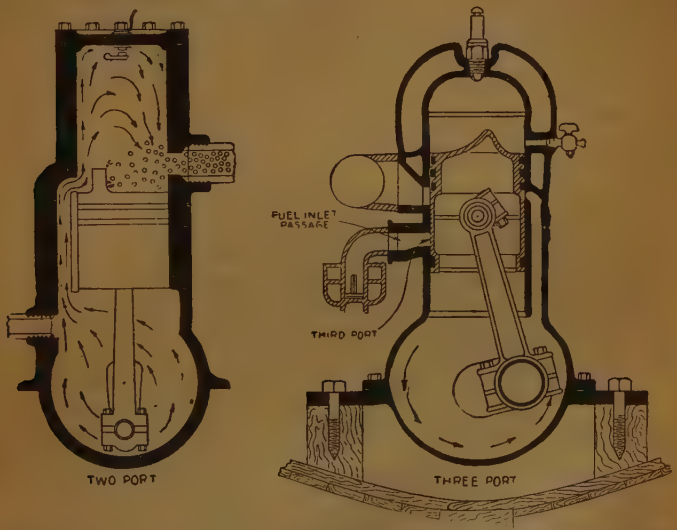
The third port furnishes a talking point for travelling salesmen.

For what service is the two cycle engine extensively used?

For marine use, especially to propel boats of small size.

Why is this?

On account of its light weight, simplicity, and small space, as well as low cost of construction.



FIGS. 463 and 464.—***Two port*** two cycle and ***three port*** two cycle engines, showing the difference in construction and principle of the third port. By comparing the two cuts it will be noticed in fig. 464, that the fuel inlet passage terminates at the cylinder bore thus the piston performs the function of a valve alternately closing the third port and opening it to the crank case. This permits the use of a carburetter without a check valve because the fuel inlet passage is never in communication with the cylinder eliminating any danger of back fire through the carburetter. Moreover the resistance and "wire drawing" due to the check valve being avoided by the third port, a slightly higher pressure is obtained in the cylinder during the suction stroke, resulting in a greater charge being admitted thus increasing the power correspondingly—though to no very appreciable extent.

Four Cycle and Two Cycle Engines Compared.—With the cycle extended to four strokes, there is more time for admission and exhaust; since these events take place at separate intervals, no chance is given for any of the charge to escape past the exhaust valve while open. Owing to simultaneous admission and exhaust in the two cycle engine, *pre-release* of the burnt gases must take place earlier than in the four cycle engine, resulting in a loss

of power which is avoided in the latter. The inefficiency of admission and exhaust of the two cycle engine becomes more marked at high speeds.

What advantages has the two cycle engine over the four cycle?

Less weight, and the absence of poppet valves with their springs, stems, push rods, and cam shafts, thus effecting a more simple construction. Since the frequency of impulses is greater, a better turning effect is secured.

In what respect does the four cycle engine excel?

Fuel economy.

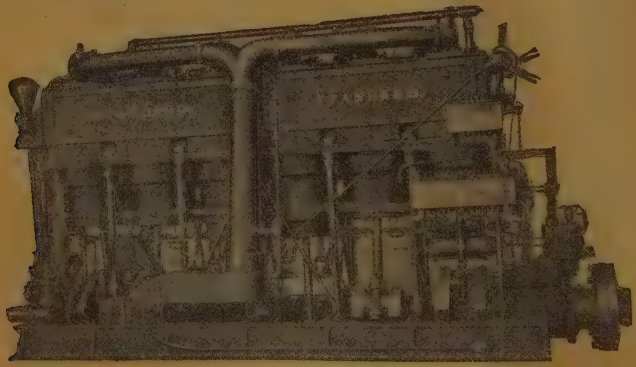


FIG. 465.—Standard 300 horse power single acting six-cylinder four-cycle engine. Size of cylinders 6×12.

Gas Engine Operation.—The gas engine derives its power or energy from the heat generated by the combustion, within its cylinder, of a mixture of gas and air in proper proportion to form an explosion.

As compared with the steam engine, the gas engine is more bulky and heavier on account of the intermittent nature of its working cycle. In operation, there are four impulses of the steam engine to one of the four cycle gas engine, hence, for equal power, its piston area must be four times that of the steam engine per pound of mean effective pressure.

What is the pressure within a gas engine cylinder during the suction stroke?

About one pound less than the pressure of the atmosphere.

Why is this?

A certain degree of suction, or pressure reduction, is necessary to overcome the frictional resistance encountered by the incoming charge as it flows through the inlet manifold, and passages.

Why does ignition occur in the combustion chamber before the end of the compression stroke?

Because the combustion requires time; if combustion begin at the proper instant before the completion of the compression stroke, the maximum pressure will be attained at the beginning

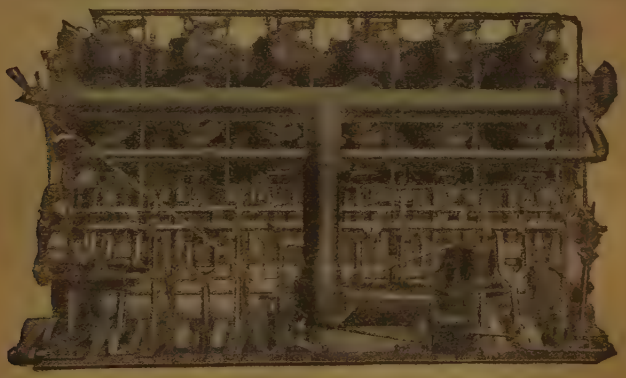


FIG. 466.—Standard double acting six-cylinder four-cycle engine, 300 horse power and above.

of the power stroke. This is desirable: 1, to avoid loss of power, and 2, to insure sufficient reduction of the temperature of the gases at the opening of the exhaust valve to prevent injury to the latter.

What conditions prevail within the cylinder during the power stroke?

At or near the beginning of the power stroke the maximum pressure due to combustion is reached; the temperature at this point is excessive, being 2,000° Fahr., or even more. As the piston advances, the gases expand, and both pressure and temperature

fall; near the end of the stroke the exhaust valve opens and the pressure at this point drops almost to that of the atmosphere.

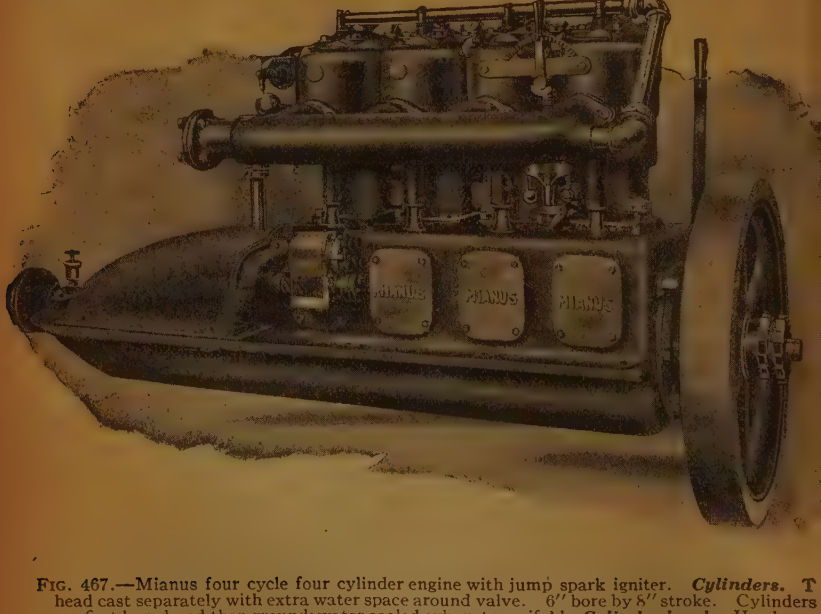


FIG. 467.—Mianus four cycle four cylinder engine with jump spark igniter. ***Cylinders.*** T head cast separately with extra water space around valve. 6″ bore by 8″ stroke. Cylinders are first bored and then ground; water cooled exhaust manifold. ***Cylinder heads.*** Heads are removable from cylinder, cast separately for each cylinder and water jacketed. By pass for cooling water is outside of and independent of cylinder. ***Pistons*** cast from the same gray iron as cylinder, insuring equal expansion. Bushed bronze removable bushings. Wrist pin turns in piston giving large bearing surface. Extra ring circling ends of wrist pin, prevents the possibility of scoring cylinder. ***Connecting rods.*** Drop forged with removable bushings. ***Piston rings.*** Lap jointed, turned eccentric, and ground, while compressed. ***Governor.*** Ball type throttling, insuring uniform speed under varying loads, making it possible to throw out clutch without racing motor. Adjustable while running and removable as a unit. ***Oiling.*** Force feed to cylinder, wrist pin, and main bearings. Splash to other bearings with leveling device so that no matter at what angle motor may be installed oil level will be same for each cylinder. Drain from outside end of main bearing to return excess oil to crank case. ***Crank case.*** Cast in one piece, including reverse gear extension, pan and rear bearing. Has removable discs, permitting the removal of crank shaft without disturbing other parts. Cam Shafts are also removable in the same way. ***Crank shaft.*** Of 45% carbon steel. 2 7/16″ diameter on all bearings reduced to 2″ on ends, providing shoulder so that should the crank be cut through lack of lubrication, new bearings may be fitted without interfering with the fit of the balance wheel or reverse gear.

How is operation possible with such high temperature as 2,000° Fahr.?

The combustion chamber and cylinder are surrounded with a jacket through which cooling water circulates. This prevents

the temperature of the cylinder walls and working parts rising beyond proper limits.

What loss results from cooling the cylinder?

Considerable heat is absorbed and carried off which otherwise might be converted into work.

The heat carried off by the cooling water represents the greatest of the several losses, being about 50 per cent. of the total heat received by the engine. This, unfortunately, cannot be avoided because, without cooling the cylinder, the parts would become red hot in a few minutes, rendering operation impossible.

How does the maximum temperature of the gas engine cycle compare with that of the steam engine?

It is about four times higher.

What quality should a lubricant possess in order to withstand the high temperature within the gas engine cylinder?

The "flash point" of the lubricant should be sufficiently high so that the latter will not ignite.

What conditions prevail during "exhaust?"

The pressure within the cylinder is somewhat higher than that of the atmosphere on account of the frictional resistance encountered by the gases in passing through the exhaust manifold and muffler.

What is the effect of this excess pressure.

It represents so much **back pressure** which opposes the motion of the piston and results in a direct loss.

The loss is due chiefly to the muffler, as its many and tortuous passages offer considerable resistance to the escape of the gases. For this reason, the muffler is usually omitted in speed contests in order that the engine may deliver its full power. When a muffler is used, a "cut out" valve is usually provided, so that full power may be obtained when required, as in ascending a hill.

What other loss occurs during exhaust?

The gases are expelled from the engine at a high temperature, thus considerable heat is carried off.

According to Thurston the distribution of heat in a gas engine is about as follows:

Heat transferred into useful work		17%
" " " to the cooling water	52%	
" lost in the exhaust gases	16%	
" " by conduction and radiation	15%	
	83%	83%
		100%

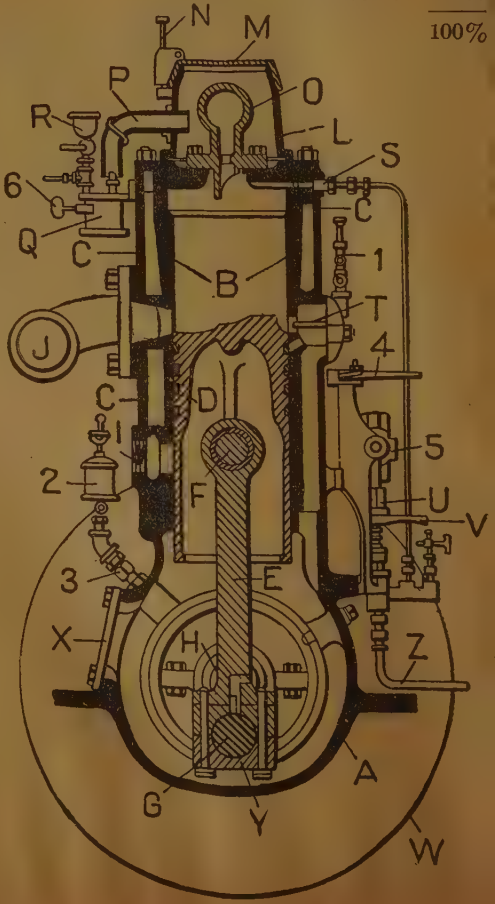


FIG. 468.—Meitz and Weiss "hot ball" igniter two cycle marine engine. It is designed to operate on kerosene, distillate, residues or crude oil. *The parts* are given below as follows:

A—Crank case.
B—Cylinder proper.
C—Water jacket.
D—Piston.
E—Connecting rod.
F—Wrist pin.
G—Crank pin.
H—Center bearing.
I—Air inlet.
J—Exhaust fitting.
L—Mantle.
M—Damper.
N—Damper screw holder.
O—Igniter ball.
P—Burner blow pipe.
Q—Burner.
R—Burner filler.
S—Injector nozzle.
T—Water feed pipe.
U—Oil supply pump.
V—Oil pump handle.
W—Fly wheel.
X—Crank case plate.
Y—Connecting rod box.
Z—Suction pipe.
1—Sight feed lubricator.
2—Center bearing lubricator.
3—Center bearing lubricator set screw.
4—Regulator handle.
5—Governor.
6—Burner gauge cock.

Gas Engine Construction.—The various parts of which a gas engine consist are of two kinds; stationary and working or moving parts.

The stationary parts are: 1, the cylinder, and, 2, crank case; the working parts are: 1, the piston, 2, connecting rod, 3, shaft, 4, fly wheel, and, 5, valve gear.

Describe the cylinder.

The cylinder is open at the end toward the crank, and closed at the opposite end, save for inlet and exhaust ports, which are opened and closed by valves.

What is the combustion chamber?

This corresponds to the clearance space in a steam engine cylinder, but its object is to provide a small space into which each charge of the fuel mixture may be compressed to considerable pressure on the compression stroke of the piston, and then ignited. Together with the volume displaced by the piston, it forms the total content of the cylinder as measured when the piston has reached the end of the **outward** stroke.

What does the size of the combustion chamber determine?

The degree of compression; the smaller the chamber in proportion to the piston displacement, the higher the pressure to which the mixture is compressed.

How is the cylinder supported?

By the crank case, which is a closed box-like structure, made up of an intermediate piece to which the cylinder is attached, and a lower piece which retains the oil.

Describe the piston.

It consists of a cylindrical box of proper size to slide back and forth in the cylinder bore, and is of the type known as "trunk piston." This form of piston performs the duties of both piston and cross head. The piston is single acting, that is, it is acted

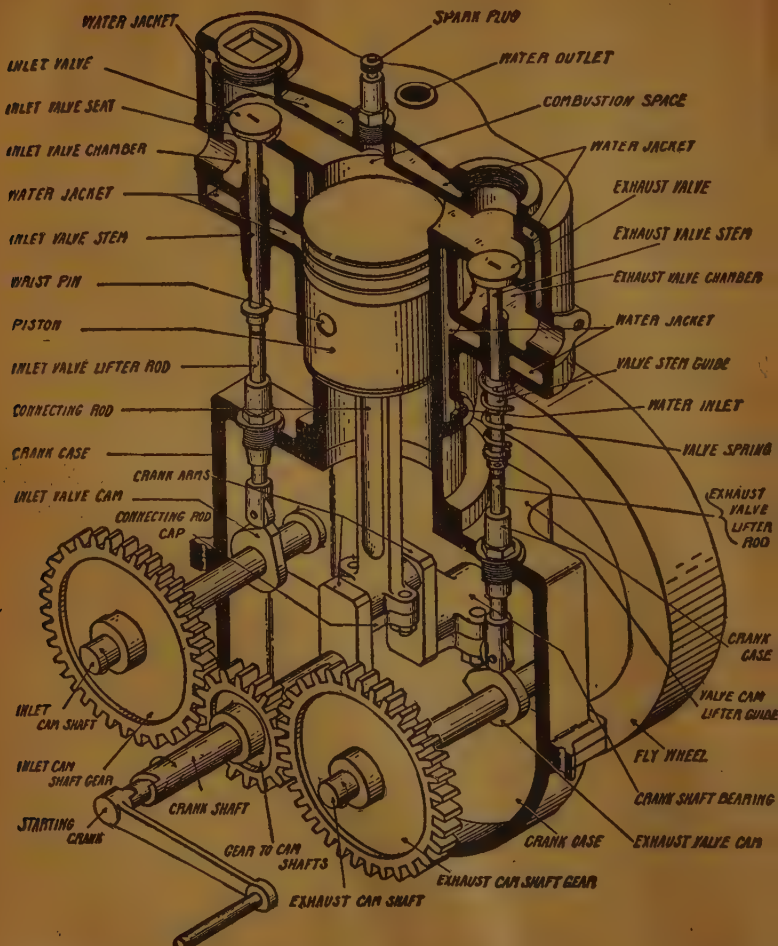
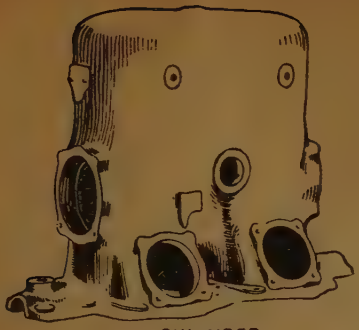
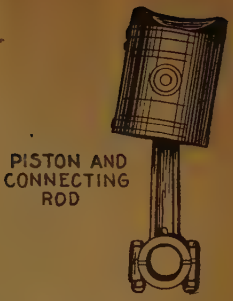
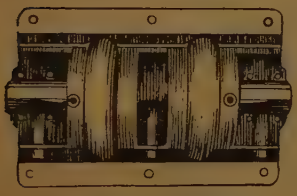
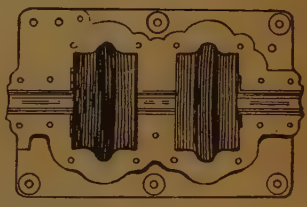


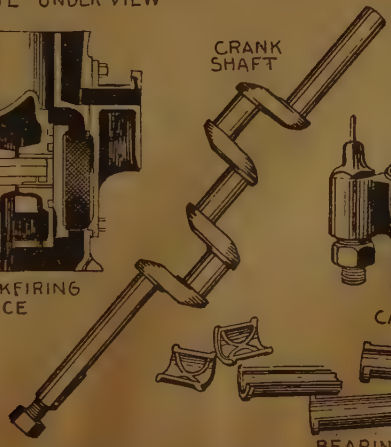
FIG. 469.—Sectional view of a four cycle gas engine showing the valve gear and other workin parts. Both inlet and exhaust valves are mechanically operated. The location of th valves diametrically opposite each other, requires a separate cam shaft for each. Thes cam shafts are geared to the engine crank shaft, and they make one revolution to every tw of the engine. When the inlet valve is operated by a spring and the engine suction, only on cam shaft is necessary, as illustrated in fig. 451.

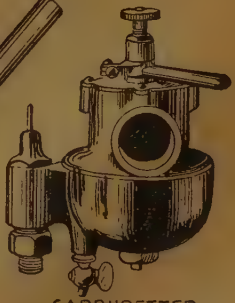


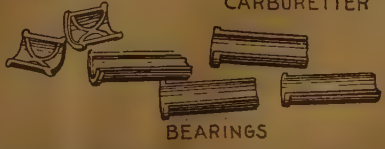












FIGS. 470 to 482.—Parts of the Gray two cycle two cylinder marine engine. Fig. 463, cylinder casting; fig. 464, piston and connecting rod; fig. 465, bed plate under view; fig. 466, bed plate upper view; fig. 467, section of cylinder showing non-back firing device; fig. 468, crank shaft; fig. 469, Krice carburetter figs. 470 to 475, bearings.

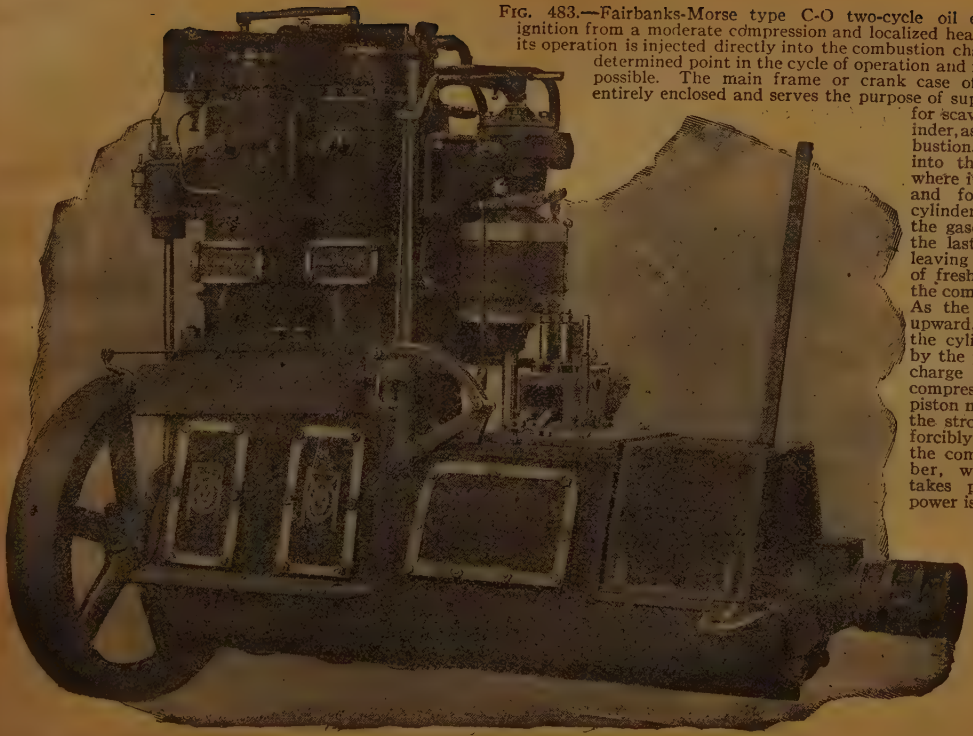


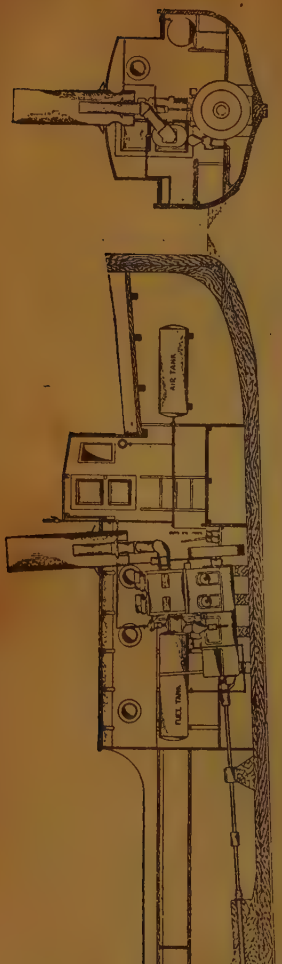
FIG. 483.—Fairbanks-Morse type C-O two-cycle oil engine securing ignition from a moderate compression and localized heat. The fuel for its operation is injected directly into the combustion chamber at a predetermined point in the cycle of operation and no preignition is possible. The main frame or crank case of the engine is entirely enclosed and serves the purpose of supplying pure air for scavenging the cylinder, as well as for combustion. Air is drawn into the crank case, where it is compressed and forced into the cylinder, driving out the gases arising from the last explosion and leaving the cylinder full of fresh air, ready for the compression stroke. As the piston travels upward, the ports of the cylinder are closed by the piston, and the charge of pure air is compressed. As the piston nears the end of the stroke, the fuel is forcibly injected into the combustion chamber, where ignition takes place and the power is developed.

upon by the power on one face only. To prevent leakage, several grooves are cut in its circumference to receive packing rings, the type generally used being known as "snap rings."

How is the piston attached to the connecting rod?

The upper end of the connecting rod is pivoted to a "wrist

FIGS. 484 to 489.—Fairbanks-Morse type C-O oil engine construction: piston and parts. The piston is long and is provided with four rings and their grooves. The rings are secured from turning by pins so that their ends cannot come in line with each other. In the piston is mounted a hardened and ground steel wrist pin.



FIGS. 490 and 491.—Installation of Fairbanks-Morse type C-O oil engine in a tug boat.

pin," which is inserted in the piston through a hole bored through its central diameter. The wrist pin is retained in place by two set screws.

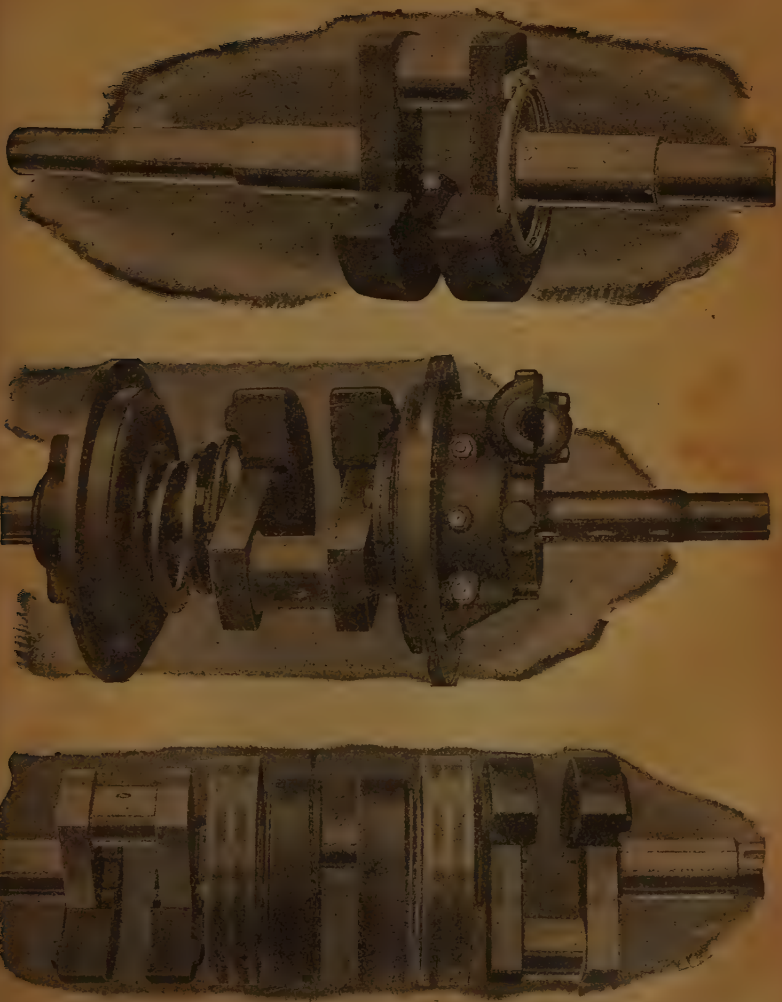
Describe the construction of the piston packing rings.

They are made from a pipe shaped casting, which is turned in a lathe to an outer diameter slightly larger than the cylinder. The inner circumference is then turned from another center, and the ring cut off and split at the thinnest section. Enough metal is removed at the split section so that the ring may be slightly compressed and again turned externally to the diameter of the cylinder while compressed. The latter operation causes the ring to bear evenly against the cylinder walls, thus making a tight joint.

Although formed of a brittle substance, piston rings have considerable elasticity, being capable of opening sufficiently to be slid over the outer diameter of the piston, and to "snap" back into the grooves.

What is the construction of the connecting rod?

It is usually of rectangular or I shaped construction, and has an adjustable bearing at each end. One end is pivoted to the

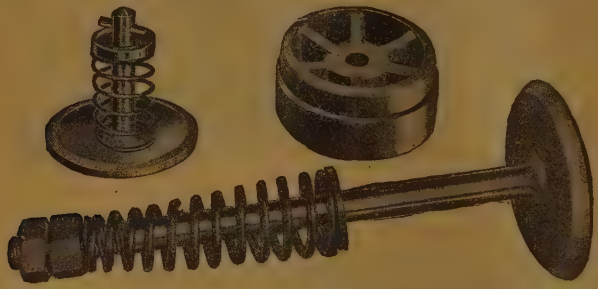


FIGS. 492 to 494.—Fairbanks-Morse type C-O oil engine construction. Fig. 492, crank shaft for single cylinder engine; fig. 493, single cylinder crank shaft showing air seal used to prevent the crank case compression blowing out the lubricant in the main bearings; fig. 494, crank shaft for three cylinder engine.

piston by the wrist pin, and the other end to the shaft by the crank pin.

Describe the crank shaft.

This is formed from a solid steel forging, and consists of a central cylindrical piece, from which radiate one or more center



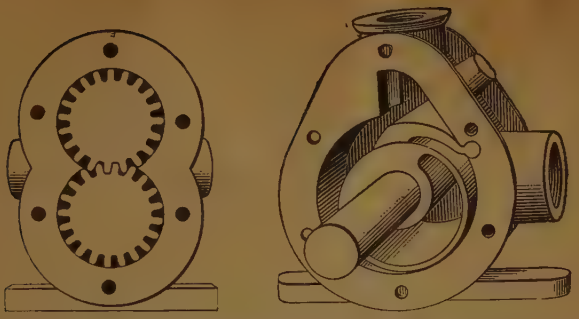
FIGS. 495 to 497.—Valves of the Automatic four cycle engine. The inlet valves are seated in a cage which is fitted with a removable cylinder head and are directly over the exhaust valves. The exhaust valves have long stems and are opened by a steel slide bearing against a nut on the outer end of the stem. This has a roller on one end operated by a cam attached to a gear meshed with a smaller steel split gear on the crank shaft. One lever operates all the exhaust valves.

cranks, corresponding to the number of connecting rods. The order of cranks depends upon the type of the engine.

FIG. 498.—Standard six cylinder four cycle marine engine.

What kind of valves are used on a four cycle engine?

Poppet or mushroom valves. These consist of metal disc beveled around one face, so as to fit into a countersink in the port; they are carried upon spindles.



FIGS. 499 and 500.—Two types of ***circulating pump*** for use in the water cooling system of gas engines.

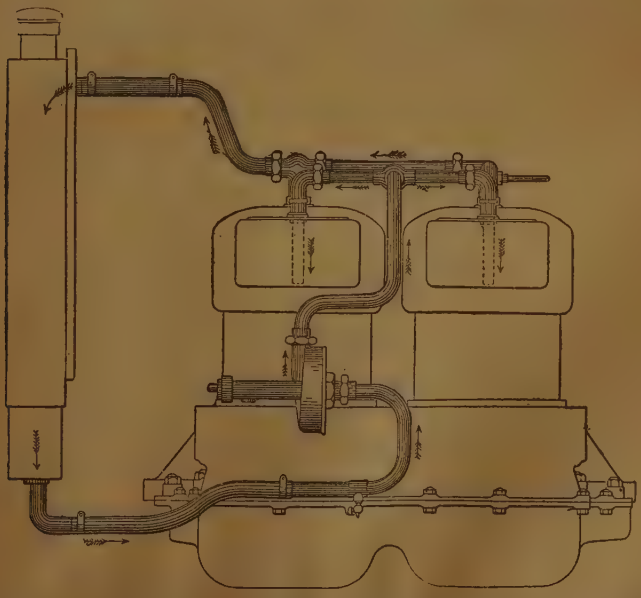
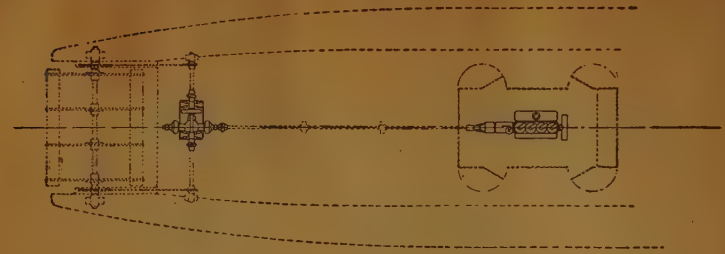
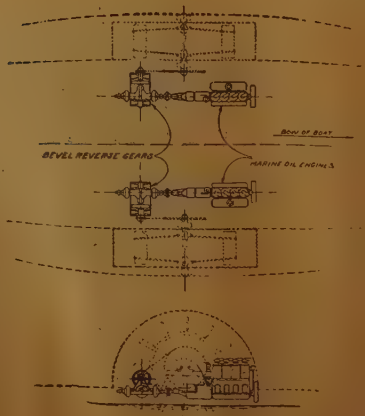


FIG. 501.—Diagram of ***cooling system.*** The cooling water is circulated by a pump which draws the water through suction pipe with inlet through side of boat below the water line and forces it upward to the cylinders, whence through vertical stand pipes it is carried clear to the bottom of the water jackets, thus insuring a thorough cooling of the cylinders. The hot water from the engine then passes off through a pipe leading overboard.





FIGS. 502 to 505.—Power plants for light draught boats. For operating a boat in shoal waters, it is necessary to provide special means for light draught propulsion. The use of twin screws driven by twin engines will be best suited for some work, while side wheel and stern wheel drives, direct from the engine, are desirable for other service. Figs. 502 and 503, show a typical installation for stern wheel drive with Fairbanks-Morse type C-O oil engine and bevel gear reverse and chain final drives. Figs. 504 and 505 show a Fairbanks-Morse installation comprising twin engines bevel gear reverse and chain final drive for side wheel boat.

How many valves are necessary?

An admission or inlet valve, and an exhaust valve for each cylinder.

Name the two types of admission valve.

The automatic, and the positive or mechanically operated valve.

The automatic inlet valve, operated by suction of the piston against the tension of a spiral spring, has been extensively used, but has been largely replaced by the positive type. The reasons for this change are that the automatic valve often sticks with gummed oil on its seat; that the spring tension may vary, thus changing the fuel pressure in the cylinder; that it is

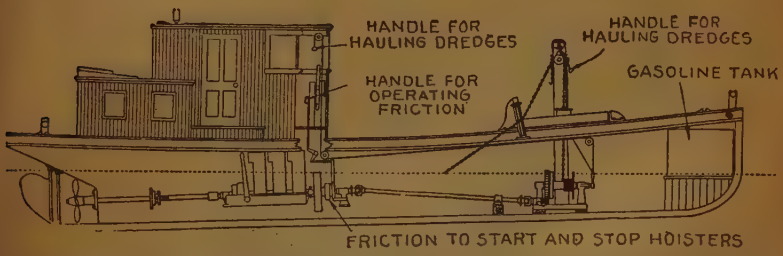

HANDLE FOR HAULING DREDGES
HANDLE FOR HAULING DREDGES
GASOLINE TANK
HANDLE FOR OPERATING FRICTION
FRICTION TO START AND STOP HOISTERS

FIG. 506.—Sectional view of oyster boat showing arrangement of engines, fore and aft style hoisters, side rollers, chain, pilot house connections for operating friction connection engine to hoisters and the line for engaging hoister drums in hauling dredges.

noisy; that its operation on high speed engines is unreliable. As against these defects, the positive inlet valve possesses the advantages of opening and closing as desired, without noise or sticking and of giving the same amount of opening at both high and low speeds. The exhaust valve is always operated mechanically.

Describe the valve gear.

The valve stem is made of sufficient length to extend down into the crank case; it enters through a bushing which serves as a guide. Attached to the end of the stem is a roller bearing, which rides on a cam attached to the cam shaft. The latter is geared to the crank shaft in such proportion that it makes one revolution

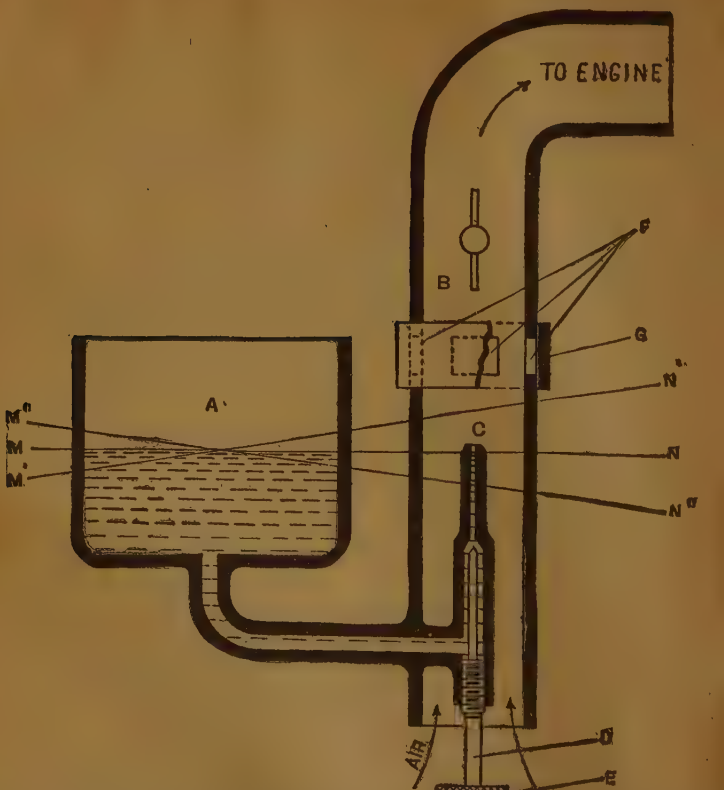


FIG. 507.—Rudimentary or simple form of ***spray carburetter*** illustrating ***carburetter principles.*** The figure shows a receiving chamber A, and a mixing chamber B, the two being connected by a small passageway or duct which terminates at the sprayer C, made adjustable by the needle valve D. The lower end of the mixing chamber B, is open to the atmosphere while the upper end is provided with auxiliary air ports F, having a collar or sleeve G, with which to adjust the opening of the ports to the atmosphere. Assume the receiving chamber A, to be filled with gasoline to a level MN, very near the elevation of the spray nozzle, and the supply replenished as it is used so that the fluid level MN, is maintained. Now, suppose the upper end of the mixing chamber to be connected with an engine as indicated. Each intake stroke of the engine will displace a volume of air, causing a partial vacuum in the mixing chamber B, the intensity of the vacuum, as will be seen, depending on the engine speed. Assuming the engine to be working at slow speed with a heavy load and the auxiliary ports F, closed by the sleeve G, the gasoline supply may be adjusted by the needle valve E, so that the engine will receive from the carburetter a mixture containing the proper proportion of gasoline vapor and air. If now part of the load on the engine be removed so that it will run say twice as fast, the same amount of air and gasoline for each charge must be received by the engine in one-half the time. Under these conditions the mixture would become too rich, that is

to every two of the crank shaft. By means of a spring, the roller bearing is held in contact with the cam.

Are two cam shafts necessary?

The valves may be operated from a single cam shaft when they are located on one side of the cylinder; when the valves are on opposite sides, two cam shafts are needed.

What is necessary for the operation of a gas engine?

The fuel, ignition, cooling, and lubrication systems.

A defect in any of these will affect the operation of the engine, hence it is desirable to clearly understand the principles involved in the working of these several systems, as later explained.

Carburetter.—The term carburetter is applied to any device wherein *gasoline vapor and air are mixed in proper proportions to form a fuel charge for an internal combustion engine.**

What are the duties of a carburetter?

It should so control the supply of air and gasoline that the

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*NOTE.—The fuel charge for a gas engine consists of about ten to sixteen parts air to one of gasoline vapor. The proportion varies according to the conditions of the atmosphere, quality of gasoline and other conditions of engine operation.

FIG. 507.—*Text continued.*

too much gasoline would be fed for the amount of air passing through the inlet at the lower end of the mixing chamber. The excess of gasoline is due to the fact that in order to get twice the amount of air through the inlet, the suction has to be more than doubled to compensate for the increased frictional resistance set up by the higher velocity of the air passing through the inlet. The suction, or degree of vacuum in the carburetter, being more than doubled, it naturally follows that more than double the amount of gasoline will pass through the spray nozzle. This excess of vacuum is caused by the expansion of the air in entering the carburetter, increasing its velocity *after expansion* more than two-fold. In order to maintain the mixture in the same proportions for varying demands, it is necessary to provide some means to keep the suction or degree of vacuum in the mixing chamber constant. The suction may be restored to its normal condition by slightly raising the sleeve G, so as to partially open the ***auxiliary air ports*** F. This allows some air to enter through the auxiliary ports, thus reducing the velocity of the entering air and relieving somewhat the suction at the lower inlet. The amount of opening of the auxiliary air ports necessary for any change of engine speed may be found by experiment. By placing a throttle valve in the passage B, between the auxiliary ports and the engine the load may be altered without any variation in the engine speed by adjusting the throttle opening. ***In actual construction,*** automatic devices are employed to maintain the gasoline in the float chamber at constant level and to adjust the auxiliary port openings to different engine speeds. In discussing the modern carburetter, the term *float chamber* is used instead of receiving chamber as it is generally known by that name, since a float is almost always used to regulate the flow of gasoline into the chamber.

resulting mixture will always contain the two ingredients in th
proper proportions. There must not be too much gasoline vapor
as fuel would be wasted either by being decomposed into soo
or unburned on account of insufficient supply of air to consum

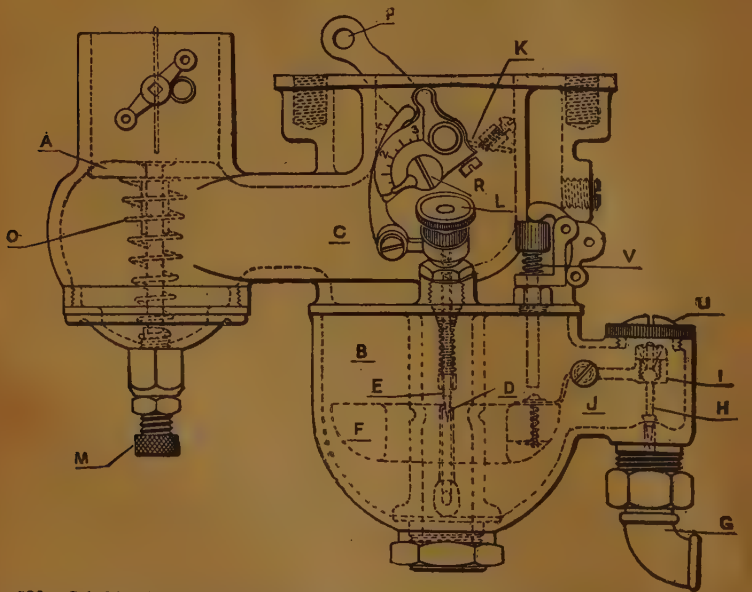


FIG. 508.—Schebler Carburetter. A compensating air valve A, adjustable by the screw M, and the spring O, controls the air supply to the mixing chamber C. Above this valve is a shutter which may be partially closed when cranking to increase the suction in order to obtain a rich mixture. The spray nozzle is located at D, and the supply regulated by the needle valve E by means of a thumb wheel L. The needle valve has two adjustments, one for high speed and one for low. At R, is the eccentric high speed adjustment. Throttle valve K, is of the butterfly type and is operated by the lever P. Heating is secured by a jacket surrounding the throttle. Gasoline enters the float chamber P, through the elbow connection G. The fuel level is maintained by the concentric float F, which regulates the supply by the inlet valve H, and the lever connection J. The float point is adjustable by the needle valve adjusting screw I, accessible by removing cap U. The carburetter is primed by the tickler or flushing pin V.

NOTE.—It has been shown in fig. 507 that the feeds of gasoline and air do not vary in the same proportion when the suction varies. A second reason for this irregularity is the fact that an initial suction is required to lift the gasoline to the mouth of the nozzle before spraying can begin. The slightest suction only is required to draw air through the air inlet; there is, however, a certain minimum suction below which no gasoline can be fed, depending on the difference in the level of the supply and the level of the spray nozzle. Hence, the importance of eliminating this difference in level is readily seen. The first requirement of a carburetter may be said to be the maintenance of the gasoline supply in the float chamber at practically the same elevation as that of the spray nozzle.

it. Again, too much air, though the mixture should ignite, would lower the temperature of combustion and thus diminish the expansion.

Carburetter Troubles.

No Flow of Gasoline.—Sometimes little, if any, gasoline will flow to the nozzle even when the carburetter is flooded in the usual manner. A quantity of dirt sufficient to stop the flow of gasoline, may have gathered on the wire gauze in the supply passage.

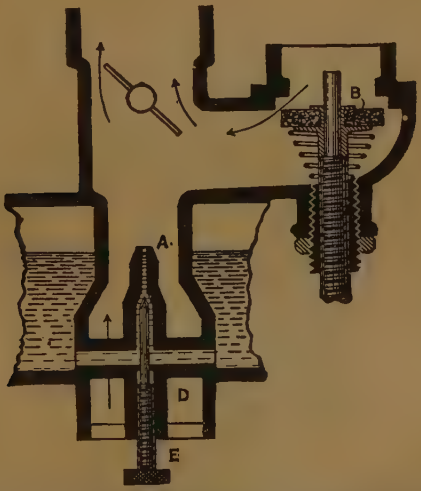


FIG. 509.—The ***mixing chamber*** with its ***appendages*** illustrating, in general, the arrangement of parts, the primary, and secondary or auxiliary air passages; auxiliary valve, spring and adjustment; the spray nozzle with needle valve and the throttle valve. The arrows indicate the direction of the entering air currents and course of mixture.

The gauze and also the float valve, spray nozzle, and connecting passage should be cleaned. In removing the needle valve to clean the spray nozzle there is no need of losing the adjustment, as after the set screw which locks the adjustment is loosened.

The needle may be turned down to a complete close, and the number of turns required noted, from which the old setting may be again obtained.

Flooding.—If not caused by a defective float, the float valve should be examined for imperfect seating. If a carburetter be not well stayed, vibration may keep the float valve off its seat, and continuous flooding result therefrom.

The leak may usually be stopped by grinding the valve on its seat with a little whiting. even grinding the seat and valve together without any abrasive, holding the valve and se in their true relative positions, and giving them a motion or rotation with moderate pressu

Carburetters having offset float chambers may flood when the car is not level, as, for instan when standing on a grade.

Flooding may be caused by dirt under the float valve; this can often be removed by d pressing the float, thus opening the float valve and flushing.

Leaking Float.—Persistent flooding is frequently due to this cause. Th presence of liquid inside a metal float is detected by shaking it, and the ho through which it entered located by heating the float and passing a lighte match over the surface, which will ignite the issuing vapor.

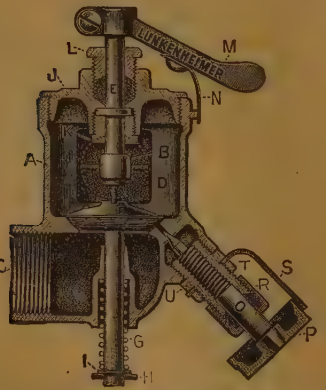


FIG. 510.—A ***vaporizer*** or ***generator valve.*** This differs from a carburetter in the absence o float chamber, and consists of a mixing chamber containing a check valve and having: 1, air inlet; 2, a gasoline inlet; and 3, an exit to engine. ***Its operation*** is as follows: On suction stroke, the partial vacuum produced in the mixing chamber A, permits the atm pheric pressure to act upon the valve F, opening same against the tension of spring G, wh is held in position by the washer I, and cotter H. At this period, the gasoline valve in port seat is uncovered and a small amount of gasoline is sprayed into the incoming volu of air and passes into the mixing chamber where the mixing is further assisted, in some signs by baffle walls. At the end of the suction stroke the pressure in the mixing cham becomes equalized with the atmosphere and the spring causes the valve F, to seat, ther retaining the mixture and shutting off any further injection of gasoline or air. The gaso supply may be adjusted by the needle valve O, operated by the thumb wheel P, which ha flat spot on its circumference on which the spring S, bears to retain the adjustment. spring can be turned to any position by loosening the lock nut T. The volume of mixt to the engine is regulated by a sliding throttle D, operated by lever M, and locked by spr N, which engages notches in a graduated dial. A vaporizer when used on a two cycle eng required no check valve between it and the engine.

To repair, the hole is enlarged with an awl, the float drained, and soldered.

Loss of Buoyancy.—A cork float sometimes loses its buoyancy by becoming saturated with gasoline.

It should be removed and thoroughly dried by placing the float in a warm place; after drying a coat of shellac should be applied.

Impure Gasoline.—Many carburetter troubles would be avoided if more care were taken to free gasoline of all dirt before its entrance into the tank.

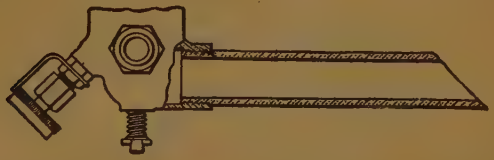
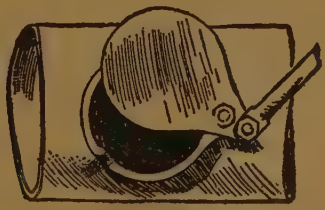
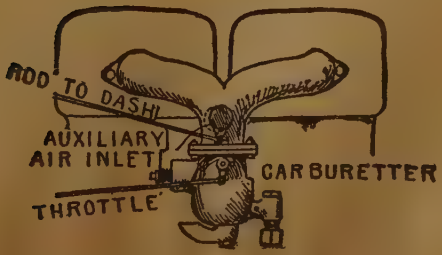


FIG. 511.—***An air inlet pipe.*** This consists of a short length of pipe threaded at one end and screwed into the air inlet of a vaporizer. A ***saving*** in fuel is secured by its use as any gasoline or vapor that may be blown into the inlet when the valve seats, is retained in the pipe and drawn into the mixing chamber during the next suction stroke. Without any extension of the inlet, this fuel would be blown out into the atmosphere and lost.





FIGS. 512 and 513.—***Hand control*** for extra air supply. A very useful attachment for economy of fuel, and for cooling and scavenging the cylinders.

When filling the tank, a strainer funnel should be used. A piece of chamois skin makes an excellent filter; if a wire gauze be used it should have a very fine mesh. In the absence of a strainer funnel, three or four layers of fine linen fitted inside an ordinary funnel may be used. The same funnel should never be used for both gasoline and water.

Stale Gasoline.—When an engine is not used for some time the gasoline in the float chamber loses its strength.

If the engine should not start, the tank valve should be closed, and the carburetter drained through the pet cock, in the bottom of the chamber. When empty, the pet cock should be closed and the tank valve opened.

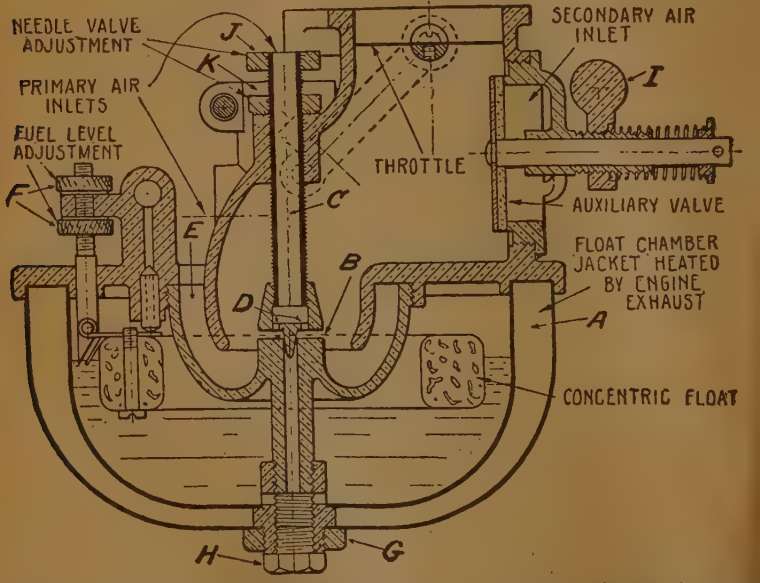
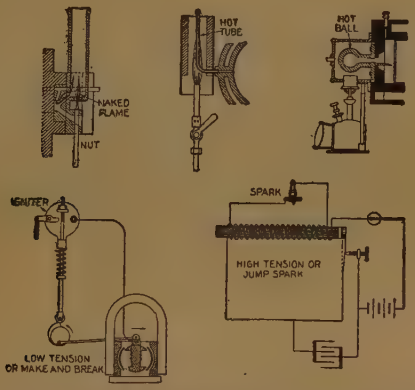


FIG. 514.—***R. O. C.*** carburetter with jacketted float chamber. In this carburetter (model D) *the fuel is heated in the float chamber before it reaches the spray nozzle, by passing some exhaust gas through the annular chamber A.* When the fuel is drawn from the nozzle at B, it is met by several fine air jets, passing through the control tube C, and the perforations D, which break the fuel up into a fine spray, which, due to the heat that it contains, immediately flies into a vapor while mixing with the air entering through the annular port E. ***The peculiar construction*** of the port E, gives it the venturi tube prineiple, the lower half of the tube being practically turned over. The fuel level in this carburetter may be raised or lowered at will by simply turning the knurled nuts F, without interfering with the action of the carburette while the engine is running, and thus the proper level is easily obtained. ***The outer jacke*** can be removed by taking off the nut G, or the float chamber drained by removing the plug H or the active inner mechanism can be exposed while in position by unscrewing the floa chamber, which is merely a drawn brass shell as all connections are part of the cover. The tension of ***the auxiliary valve spring*** is adjusted by turning the wing nut without interfering with the action of the valve. ***The needle valve adjustment*** is made by turning the air tube C, by means of its knurled head J, and it is held in any position by tightening the knurled jam nut K. ***An interesting feature*** is that all adjustments, including the removal of the float chamber, are made without even the use of a screw driver. Model A differs from the illustration simply by the absence of the jacket surrounding the float chamber.

Water in Gasoline.—This is generally indicated when the engine runs irregularly, and finally stops.

Freezing of Carburetter.—When water enters the float chamber it settles to the bottom and in cold weather prevents the action of the float by freezing; the water is also liable to enter the spray nozzle where it may congeal. When heavy demands are made on a carburetter it becomes very cold, as the heat required to effect evaporation is much more than that available from the entering air. Under extreme conditions moisture is deposited in the form of frost, indicating a temperature in the carburetter too low for good working. These conditions may be avoided by jacketing or heating the air supply.



FIGS. 515 to 519.—Various methods of ignition. Fig. 515, naked flame; fig. 516, hot tube; fig. 517, hot ball; fig. 518, low tension electric or make and break; fig. 519, high tension electric or jump spark.

Cold Weather.—In extremely cold weather it may be necessary to warm the carburetter and admission pipe. This may be done by pouring boiling water over them.

Cranking.—So far as carburetter action is concerned, **a few quick turns of the crank** will be more likely to start the engine than ten minutes or more of slow grinding.

Misfiring.—This is frequently caused by too weak, or too rich a mixture. Misfiring allows the unburnt charge to accumulate in the exhaust pipe and muffler; sometimes accumulated gas is ignited by a later charge, causing a very loud report like a tire explosion. Misfiring on slow speed may be caused by too weak a mixture due to having the float set too low, or by leaks in the pipe and connections between the throttle and the engine.

Ignition.—It is of prime importance that the operator of a gas engine acquire a thorough knowledge of ignition. Many of the

troubles still encountered, notwithstanding numerous improvements, have arisen from failure of the ignition system to perform its proper function. The engine may operate with an imperfect fuel mixture, if the ignition system be in working order, but any defect in the latter will in nearly every case cause the engine to misfire or stop.

Numerous devices have been tried to fire the charge in gas engines. In the early days, a flame behind a shutter was used, the latter being opened at the proper moment. Sometimes the flame was blown out by a too violent

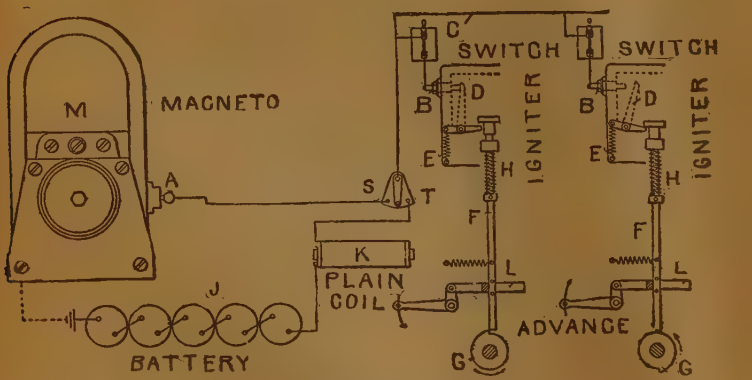


FIG. 520.—A *low tension* or *make and break* ignition system. *In operation*, as the nose of the cam G, passes rod F, the latter suddenly drops by the action of spring H. The head of the rod, which has been raised by the cam somewhat above the arm of D, will, in its descent, strike D, a blow which abruptly breaks contact between D, and B, thus producing a spark. When not acted upon by the head of the rod F, D, is held in contact with B, by the spring E.

explosion, so this method gave way to a porcelain tube that was kept at white heat by an interior flame. The tube being subject to breakage, spongy platinum, heated by compression, was next tried and found to work, if not too moist from watery vapor in the gas mixture, or if the engine speed were not too high. Electricity is now universally used. Hence, in order to gain an understanding of ignition principles, it is necessary to have at least an elementary knowledge of electricity, therefore a study of the electrical section of this book will be found helpful.

What names are given to the two methods generally used?

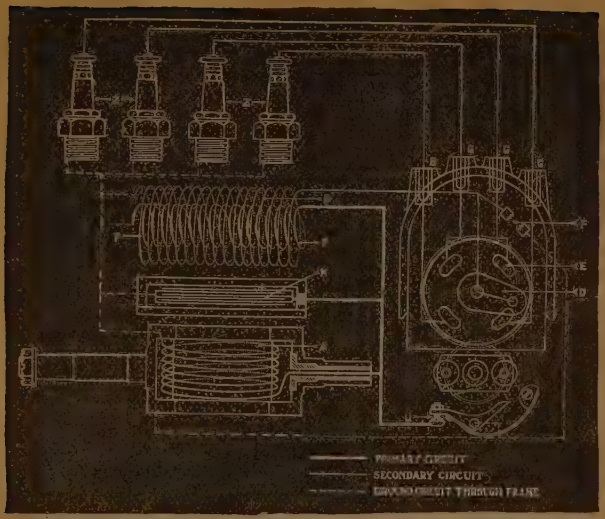


FIG. 521.— Circuit diagram of a magneto with self contained coil. A is the armature inding P, primary of transformer; S, secondary of transformer; D, distributing brush carrier; E, contact segments; F, safety spark gap; G, terminals to plugs; U, interrupter; Z, spark plugs. ***In operation,*** alternating current flows from the armature having two points of maximum pressure in each armature revolution. As the current leaves the armature, it is offered two paths: 1, the shorter through the interrupter U to the ground, and 2, the longer through the primary P of the induction coil to the ground. A third path through the condenser K is only apparently available; it is obstructed by the refusal of the condenser to permit the passage of the current, as the condenser will merely absorb a certain amount of current at the proper moment, that is at the instant of the opening of the interrupter. The interrupter being closed the greater part of the time, allows the primary current to avail itself of the short path it offers. At the instant at which the greatest current intensity exists in the armature, the interrupter is opened mechanically so that the primary current has no choice but must take the path through the primary P of the induction coil. A certain amount of current is at this instant also absorbed by the condenser K. This sudden rush of current into the primary P of the induction coil, induces a high tension current in the secondary winding S of the coil which has sufficient pressure to bridge the air gap of the spark plug. The sharper the rush of current into the primary winding P, the more easily will the necessary intensity of current for a jump spark be induced in the secondary winding S. ***The distribution of the current*** in proper sequence to the various engine cylinders is accomplished as follows: the high tension current induced in the secondary S of the induction coil is delivered to a distributing brush carrier D that rotates in the magneto at half the speed of the crank shaft of the engine. This brush carrier slides over insulated metal segments E—there being one for each cylinder. Each of these segments E connects with one of the terminal sockets that are connected by cable with the spark plugs as shown. ***At the instant of interruption*** of the primary current, the distributing brush is in contact with one of the metal segments E and so completes a circuit to that spark plug connected with this segment. Should the circuit between the terminal G and its spark plug be broken, or the resistance of the spark plug be too great to permit a spark to jump, then the current might rise to an intensity sufficient to destroy the induction coil. To prevent this what is known as a safety spark gap is introduced. This will allow the current to rise only to a certain maximum, after which discharges will take place through this gap. ***In construction*** the spark discharges over this gap are visible through a small glass window conveniently located.

The first is known as the ***make and break*** or ***low tension,*** the second, the ***jump spark*** or ***high tension.***

Describe a low tension system.

In this system there is a device known as an igniter, placed in the combustion space of the engine cylinder. This consists of two electrodes, one of which is stationary and the other movable. The stationary electrode is insulated, while the other, having an arm within the cylinder and placed conveniently near, is capable of being moved from the outside so that the arm may come in

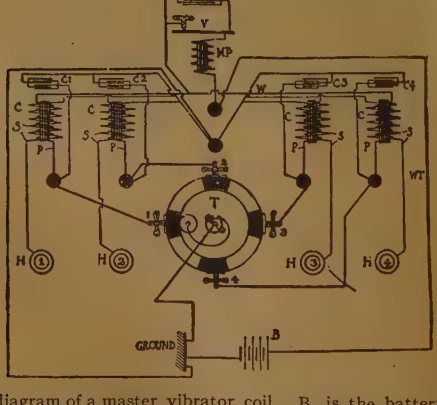


FIG. 522.—Circuit diagram of a master vibrator coil. B, is the battery; C, the unit coils C1, C2, etc., the condensers; P, the primary windings and S, the secondary windings; H1 H2, etc., the spark plugs; T, the timer; MP, the master primary; V, the vibrator; W, th common primary connection; 1, 2, etc., the stationary contacts of the timer.

contact with the stationary electrode and be separated from th latter with great rapidity. The circuit includes a **primary induc tion coil.** Current may be derived from either a primary battery storage battery, or low tension magneto.

The sudden breaking of the circuit by the quick separation o the electrodes produces an electric arc or ***primary spark*** cause by the ***inductance***—that is, by the "inertia" or tendency of th

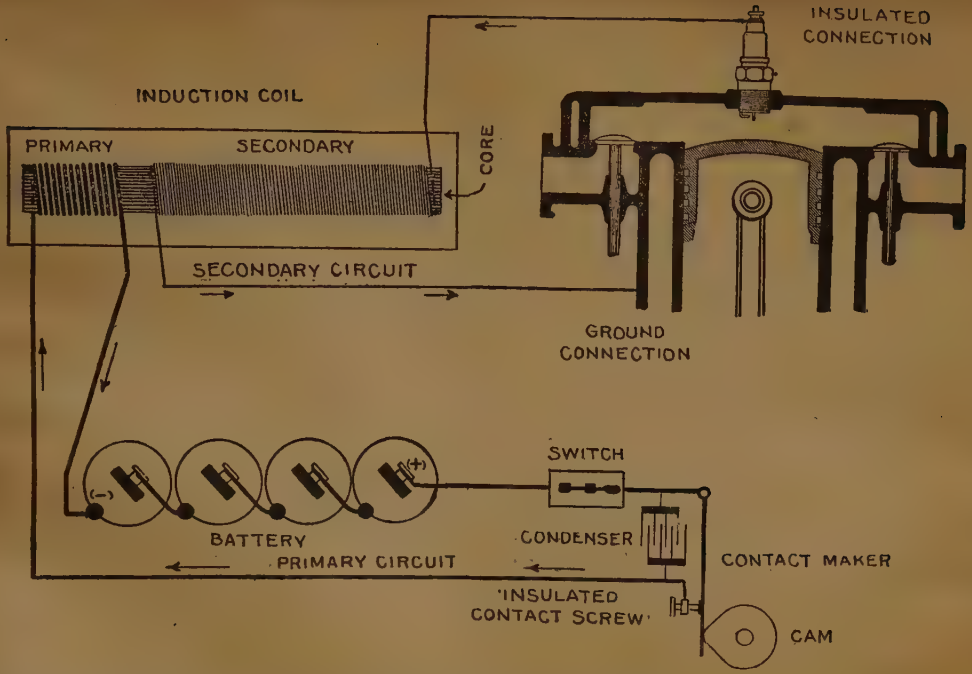


FIG. 523.—Diagram illustrating the principles of ***high tension*** or ***jump spark ignition.*** The nose of the cam, in revolving, engages the *contact maker* which completes the primary circuit and allows the current to flow from the battery through the primary winding of the coil; this magnetizes the core. The primary circuit is now broken by the action of the cam and magnetic changes take place in the coil which induce a momentary high tension current in the secondary circuit. The great pressure of this current forces it across the air gap of the spark plug and, as it bridges the gap, a spark is produced. The arrows indicate the paths of the currents

current to continue flowing after the separation of the contact points.

What are the general principles upon which high tension or jump spark ignition is based?

An automatic device is placed in the primary circuit, which closes and opens it at the time a spark is required. When the circuit is closed, the primary current flows through the primary winding of the coil and causes a secondary current to be induced in the secondary winding. A spark plug being included in the secondary circuit, opposes the flow of the current by the high resistance of its air gap. Since the pressure of the secondary current is sufficient to overcome this resistance, it flows or "jumps" across the gap, and in so doing, intense heat is produced, resulting in a spark.

What is synchronous ignition?

A system of high tension ignition in which a **distributer** and a **single coil** are used for the several cylinders of a multi-cylinder engine.

Gas Engine Troubles.—If the engine will not start it should be ascertained (preliminary to hunting for carburetter troubles) that there is some gasoline in the tank and that the valve on the pipe leading from same is open.

The carburetter is too often blamed for faulty engine performance, which should be attributed to defects in the ignition system. Such symptoms as fouled plugs, black smoke in the exhaust, etc., point at once to the carburetter, but in cases where such obvious signs are wanting, the ignition system should first be thoroughly examined.

After Firing.—This is usually caused by the delayed ignition or combustion of the previous charge, due to a mixture that is too rich or too weak, hence it burns slowly with continued combustion after passing into the exhaust.

Weak Explosions.—Quite regular, but weak explosions may be due to either too rich, or too poor a mixture, or to the loss of compression.

A hiss inside the cylinder indicates a leaky piston ring, or that the openings of the piston rings are in line.

A little soapy water around the relief cock, spark plug, or other opening into the combustion space will indicate a loss of compression by the formation of bubbles.

Ignition Troubles.—To successfully cope with ignition troubles there are two requisites: 1, a thorough knowledge of the system used, and 2, a well ordered course of procedure in looking for the cause of the trouble.

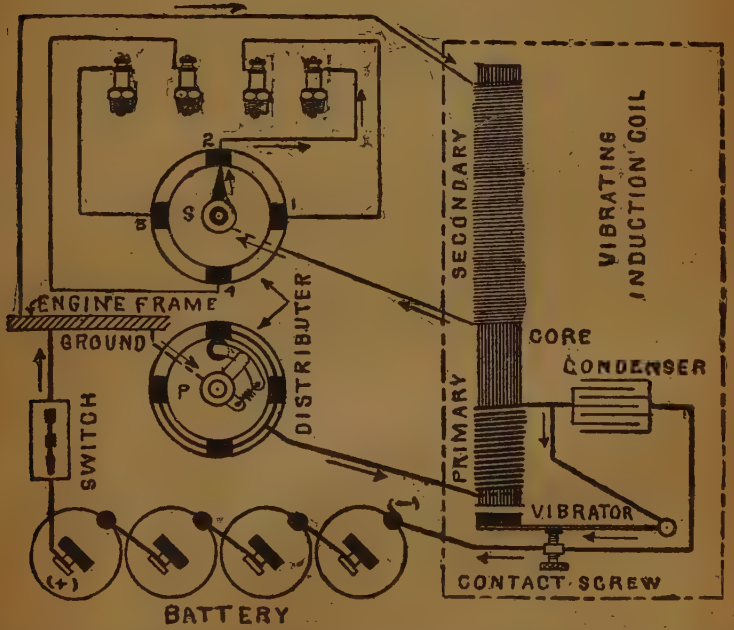


FIG. 524.—Diagram illustrating the principles of ***synchronous ignition.*** For clearness, the primary and secondary elements of both the coil and the distributer are shown separated. When the primary rotor of the distributer completes the primary circuit current from the battery flows and vibrator operates, making and breaking the current with great frequency. A high tension current, made up of a series of impulses, is induced in the secondary circuit, and distributed by the rotor arm, during its revolution, to the several cylinders in the proper order of firing.

In many ignition systems the chief difficulty encountered in the location of defects arises from the fact that faults in different portions of the circuit sometimes makes themselves manifest by the same symptoms. If each defect had

its individual symptom, locating the trouble would be comparatively easy, but, as it is, it is sometimes quite difficult to find the defective parts. In general, the following method should be adopted to locate ignition troubles:

1. The source of current supply should be examined; if a battery, each cell should be tested separately, and any one found to be weak, removed. If a magneto be used, it should be disconnected, and the armature turned by hand; in case the field magnets have not lost their proper strength, the armature should turn perceptibly hard during certain portions of each revolution.

2. The primary circuit should be examined for breaks; all connections made bright and secured firmly by the binding screws, and the timer contacts cleaned.

3. The spark plug points should be cleaned and the air gap made the proper length—about one thirty-second of an inch.

Testing the Spark Plug.—The spark plug should be unscrewed and placed on the cylinder without disconnecting the wire to the insulated electrode; the body of the plug only should touch the metal of the cylinder.

On cranking the engine the spark should be "fat" if everything be in good condition; if a weak spark be produced it may be due to either a loose terminal, run down battery, or badly adjusted vibrator. When no spark can be obtained the entire system must be examined and tested, beginning at the battery.

Plug Testing in Multi-Cylinder Engines.—All nuts are removed from the plug, leaving the high tension wires in place. After starting the engine all wires are grounded except one, thus running the engine on one cylinder.

In case there be no misfiring after testing at various engine speeds, it can be taken for granted that the plug is sound. The remaining plugs are tested in the same manner. When a multi-unit coil is used, a faulty plug may be located by holding down all the vibrator blades but one so that only one spark plug operates. By running each cylinder separately by this means it can easily be ascertained which plug is defective. Some coils are provided with little knobs for cutting out cylinders in the manner just described.

Complete Break in the Wiring.—The engine is placed upon the sparking point, the primary switch closed, and the two terminals of the suspected wire touched with a test wire. A flow of current indicates a break.

Partial Break in the Wiring.—A partial break, or one held together by the insulation, may sometimes be located by bending the wire sharply at successive points along its length, the engine being at the sparking point and the switch closed as before.

Primary Short Circuits.—The primary wires should be disconnected from the coil, leaving the ends out of contact with anything. There is a short circuit if on touching the switch points momentarily a spark appear.

A short circuit may sometimes be overcome by clearing all wires of contact with metallic bodies, and pulling each wire away from the others which were formerly in contact with it.

Secondary Short Circuits.—The secondary lead from the spark plug should be disconnected. Under this condition the high tension current may sometimes be heard or seen discharging from the secondary wire to some metallic portion of the car.

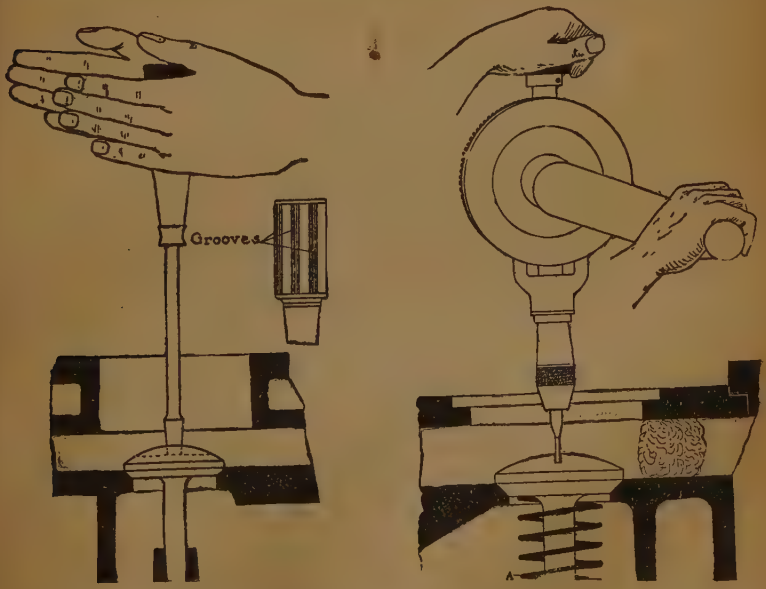
Water in contact with the secondary wire will sometimes cause a short circuit unless the insulation be of the best quality.

The Primary Switch.—This portion of the primary circuit sometimes causes trouble by making poor contact. This is generally due to the deterioration of the spring portion of the metal, which gradually loses its resiliency.

Snap switches sometimes fail through the weakening of the springs which hold them in the "on" or "off" position. The contacts of a switch should be kept in good condition.

Primary Connections.—All binding posts and their connections should be clean and bright.

The wires should be firmly secured to the binding posts, as a loose connection in the primary circuit is often the cause of irregular misfiring or the stopping of the engine.



FIGS. 525 and 526.—Method of using a screw driver for valve grinding. A handful of waste or a cloth is put in the valve port to protect the cylinder, and the valve face coated with a paste of the emery powder and oil and put in place. The handle of the screw driver is now held between the palms of the hands as in the sketch, and a series of oscillations through a small arc given to the valve by moving the palms in opposite directions. After about thirty of these oscillations have been given, the valve is lifted from its seat, given a half turn, and reseated for further grinding in the same manner. This operation should be continued with occasional additions of oil and emery, until the valve face and the seat appear to be bright for their full width around the circle.

FIG. 527.—Method of grinding a valve with a drill stock. A screw driver bit is inserted in the chuck and the operation conducted as in the case where a screw driver is used. The crank should be rocked through a small arc instead of being rotated. The spring A, is fitted within the valve chamber to unseat the valve when it is desired to examine it.

Vibration.—Since the wires are subject to constant vibration, a number of strands of fine wire is better than a single heavy wire, as the latter is more liable to be broken.

In securing the wire to a binding post, care should be taken that all the strands are bound.

Engine Misfires and Finally Stops.—This may be due to exhaustion of the battery, and is indicated by a weak spark and very faint vibrator action.

Engine Suddenly Stops.—This is generally caused by a broken wire or loose switch which does not stay closed.

In the case of a single cylinder, the broken wire may be either in the primary or secondary circuit, if a multi-cylinder engine, the break is in the primary circuit.

Engine Does Not Start.—Usually caused by: 1, primary switch not closed, 2, battery weak or exhausted, 3, entire or partial break in wire, 4, loose terminal, 5, moisture on spark plug, 6, fouled plug, 7, spark too far retarded or advanced, or, 8, too slow cranking with magneto ignition.

Engine Runs Fitfully.—Frequently results from a partial break in the wiring, especially in the primary circuit.

Pre-ignition.—Caused by: 1, some small particle in the cylinder becoming heated to incandescence, 2, the electrodes of the spark plug becoming red hot, or, 3, intermittent short circuit in the primary.

Engine Runs with Switch Open.—Usually caused by: 1, over-heated engine or plug points, 2, primary short circuit, 3, defective switch, or, 4, an incandescent particle inside the cylinder.

Engine Misfires.—This may be caused by: 1, weak battery, 2, partial break in conductor, 3, loose or disconnected terminal, 4, intermittent short circuit in the secondary, 5, faulty action of either timer or vibrator contacts, 6, bent vibrator blade, 7, faulty spark plug, or, 8, air gap too large.

Knocking of Engine.—Too much advance of the spark sometimes produces this effect.

Knocking in the Cylinder.—The form of unusual noise commonly described as "knocking" consists of a regular and continuous tapping in the cylinder, which is so unlike any sound usual and normal to operation that, once heard, it cannot be mistaken.

Too much advance of the spark sometimes produces this result. As mentioned by numerous authorities, the placing of the spark plug in the exact center of the combustion space occasions a peculiarly sharp knock, which may be stopped by advancing or retarding the spark from the one point of trouble. This explanation of the trouble is questioned by others, and is probably over rated.

Loss of Power without Misfires—This may be due to badly adjusted coil contacts, poor spark, or incorrect timing.

Explosions in the Muffler—These are usually caused by misfiring, partially charged storage battery, or, by one cylinder not working.

Engine Defects.

Defective Compression.—Faulty compression is likely to prevent the ignition of the charge. The deficiency or otherwise may be ascertained by turning the engine around to the point of compression, when all valves are or should be closed.

If but slight resistance be encountered, it is apparent that the charge is escaping through one of the valves or past the piston. The various channels of escape may be investigated as follows:

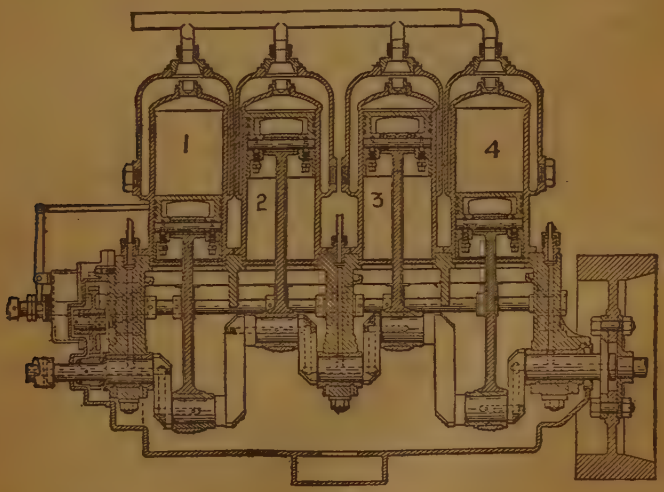


FIG. 528.—A typical four cylinder engine, showing position of cranks and working parts, including secondary shafts.

Leaky Valves.—The valves, usually closed by their springs, may become hung up, from various causes.

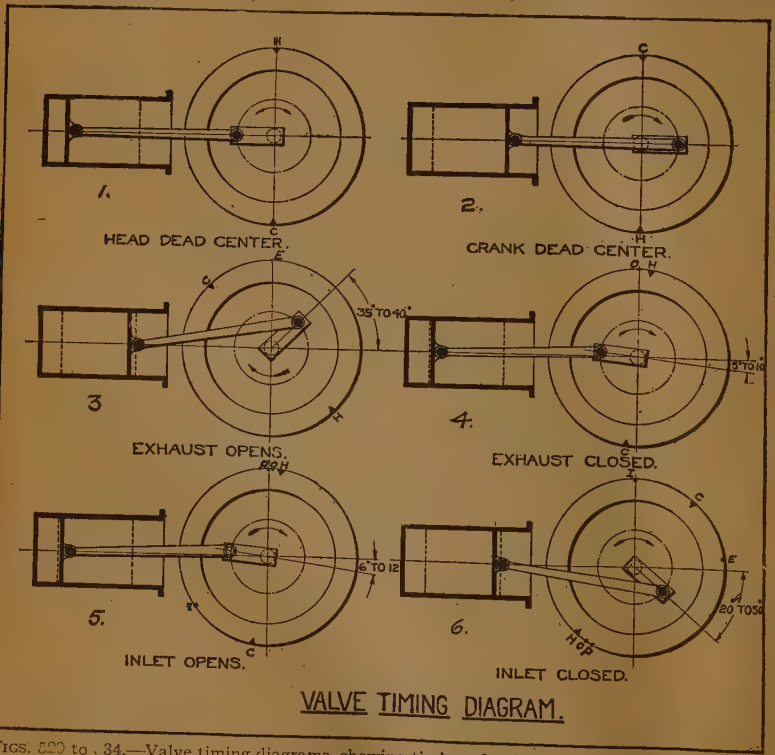
The stems may be clogged, which can be ascertained by manipulating them by hand or by a lever; this may be remedied by taking apart and cleaning off the caked oil, the same applying to an obstruction which may prevent the valve closing. A worn valve may leak; this is only to be remedied by grinding in or renewal. In a new engine, the stem of the valve may bind in the seat, through fitting over-tight, which may be remedied by easing the stem with fine emery cloth and applying a little lubricant, cylinder oil for inlet and kerosene for exhaust valves.

Leaky Exhaust Valve.—Other causes may militate against the effective operation of an exhaust valve.

The spring may weaken through over-heating, or slackening of its compression nut, so that it has not sufficient tension to keep the exhaust valve closed against the suction of the charging stroke.

This is remedied by renewal of the spring, tightening of the compression nut, by inserting a washer under the spring (or weighting the spindle) for a temporary repair.

Lack of end play between the roller or wiper on the cam shaft and the valve stem, due to expansion of the later, may prevent the valve seating. This may be obviated by filing or regulating the contact.



FIGS. 529 to 534.—Valve timing diagrams, showing timing of valves for one cylinder engine.

Leaky Piston.—The passage of the compressed charge, past the piston, is indicated by a whistling sound. This may be due to broken or worn rings, or to wear of the cylinder. If the cylinder be badly worn, reboring is likely to be necessary.

Squeaking in the Engine.—Squeaking, evidently caused by the rubbing of one part upon another, is a sure sign of insufficient lubrication, probably in some bearing outside of the cylinder, although perhaps at the wrist pin of the

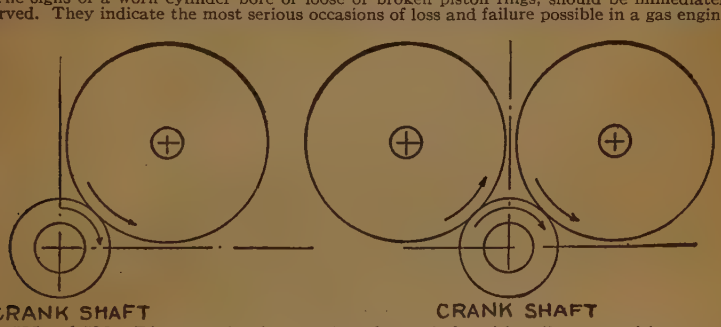
piston. Faulty lubrication between the piston and cylinder wall would produce much more serious results than noise, as already stated.

Wheezing.—A wheezing sound, evidently due to the escape of gas or air under pressure, and sometimes amounting to a squeak, is often caused by loose or worn piston rings or scoring of the cylinder bore. The causes of this trouble are, as already suggested:

1. Deficient lubrication, producing a tendency to seize.
2. Misalignment of wrist pin and crank pin, or a bent rod, causing the bore to wear oval.

This trouble generally results from repeated backfiring, from an over-early spark and the other causes specified.

The signs of a worn cylinder bore or loose or broken piston rings, should be immediately observed. They indicate the most serious occasions of loss and failure possible in a gas engine.



FIGS. 535 and 536.—Diagrams showing rotation of cam shafts with a direct gear drive.

FIGS. 537 and 538.—Diagrams showing rotation of cam shafts when an intermediate idler is used.

Hissing or Puffing Sounds.—While leakage at the piston gives forth a sound that may be described as "wheezing," on account of the imperfect venting of the compressed gas, the escape of such gas into the atmosphere is accompanied by hisses or puffs. Such sounds indicate the probability of leaks:

1. At the gasket in the cylinder head, if a joint exists above the piston.
2. At the insertion of the spark plug, due to a worn screw thread or washer.
3. At the valve seats, due to pitting or to an improper fit of the valve.

Leaks of this character are liable to occasion continuous cracking sounds during the firing stroke.

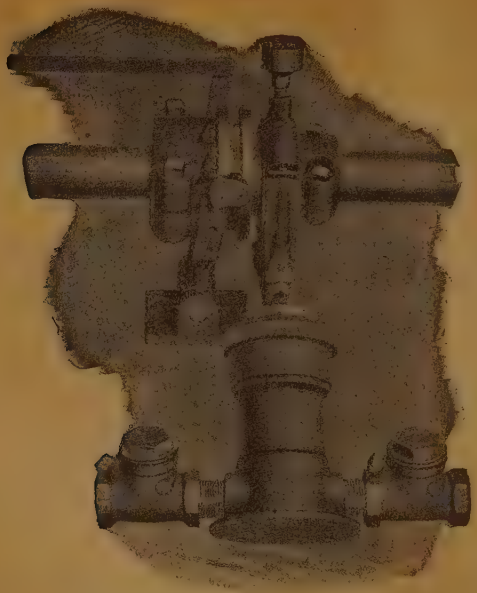


FIG. 539.—Kahlenberg bilge pumps with shaft drive, arranged with clutch so it can be start
or stopped while engine is running. The pump is with inner and outer glands with bro
panel.

CHAPTER THIRTY-THREE

GAS PRODUCERS

Producer Gas.—The gas formed by a producer is the product of an incomplete or retarded combustion of the fuel. This is effected by burning the latter in a bed, *several feet in thickness*, within the *generator* or producer proper. The heated gases and flame from the portion nearest the air supply, where combustion is more or less rapid and complete, have to pass through the remainder of the bed, distilling gases from the latter in their transit. The processes of combustion within the generator may be described as follows:

The oxygen O_2 of the atmosphere combines with the fuel in the first portion of the bed, and the ensuing combustion results in the formation of carbon dioxide CO_2, that is to say, each atom of carbon combines with two atoms of oxygen. This means that each pound of carbon requires $2\frac{2}{3}$ pounds of oxygen, the combination resulting in the formation of $3\frac{2}{3}$ pounds carbon dioxide, and, at the same time, imparting about 14,500 heat units to the mass of fuel.

The effect of this process is that the $3\frac{2}{3}$ pounds of carbon dioxide assimilate another pound of carbon, forming $4\frac{2}{3}$ pounds of carbon monoxide, which is equivalent to the evolution of $2\frac{1}{3}$ pounds of the latter gas for each pound of carbon consumed.

Processes Within the Producer.—The first two reactions i the generator constitute what is termed incomplete combustion consisting of the formation of ***carbon dioxide*** and the decom position of the compound into the ***monoxide.*** The result o the process is the same as if the pound of carbon had been burn directly to carbon monoxide, thus developing 4,451 *B.t.u.* fo each pound of C, burnt to CO. This heat is apparent as th sensible heat of the fuel bed and generator.

The carbon monoxide may be caused to combine with fresh oxygen at an time after it has left the producer, this second combustion to CO_2 being ac companied by the evolution of 14,544—4,451 = 10,093 *B.t.u.*, the heat valu of CO to CO_2 per pound of carbon contained.

Now, atmospheric air is a mechanical mixture of oxygen, which support combustion, and of nitrogen, which is an inert gas serving as a diluent. Th proportions, by weight, are: oxygen, 23 per cent.; nitrogen, 77 per cen Therefore, accompanying and diluting the 2½ pounds of carbon monoxid resulting from the reaction in the producer, there will be about 4.46 pounds nitrogen, the whole forming about 6.8 pounds of lean gas.

Use of Steam in Connection with Gas Producers.—The objec of the gas producer being the generation of a combustible ga of high heat value, it is desirable to use as little as possible the inherent heat energy of the fuel during its gasificatio The only sensible heat necessary is that which raises the fu to incandescence so as to reduce the carbon dioxide to monoxid

Now, there are some 4,451 heat units generated in burning a pound carbon to carbon monoxide, and as only part of this heat passes away wi the gases or is dissipated by radiation from the generator, it may be sa that there is a surplus of about 2,500 *B.t.u.* per pound of carbon over and abo what is necessary for the working of the furnace. This extra heat requir to be utilized in order to get the greatest efficiency from the generator and keep the temperature down, a temperature of 1,900° Fahr. having been fou to give a minimum of CO_2 or a maximum of CO.

This surplus of heat is utilized in an effective manner by the introducti of steam into the generator.

Each pound of steam on being decomposed, liberates ⅑ pound hydrog and ⅞ pound oxygen, the latter combining with ⅔ pound carbon to form 1 pounds of carbon monoxide, this extra amount being produced without t introduction of any more inert nitrogen into the apparatus.

FIG. 540.—A 200 horse power Standard (Akerlund type B) suction down draught producer operating a suction dredge. ***The illustration shows*** the dredge working in deep salt water. Salt water is used in the scrubber. Full load operating, 24 hours per day is essential.

In order to effect the decomposition of one pound of steam, in the presence of incandescent carbon, 6,800 heat units are necessary, and as there are only about 2,500 *B.t.u.* available for the purpose from the burning of each pound of carbon, the quantity of steam that can be taken care of is $\frac{2,500}{6,800}$ or about .37 pounds. This yields about .325 pounds oxygen which combines with about .245 pounds carbon, yielding .57 pounds of the monoxide, which is equivalent to saying that about one-fifth of the total carbon can be gasified by the aid of the steam. The hydrogen liberated will be about .033 pounds for each pound of total carbon gasified in all reactions.

Conditions Affecting the Use of a Producer.—For ordinary producers, working in connection with gas engines, it is necessary to wash and filter the gases before they are used, in order to remove tarry or carbonaceous particles which would be detrimental to the working of the engine. For the same reasons many engineers prefer to use anthracite coal or coke to the exclusion of bituminous or soft coals.

Classes of Gas Producer.—With respect to the control of the air passing through the machine, producers are divided into two general classes:

1. Pressure producers;
2. Suction producers.

In the pressure system, the air required for the generation of the gas is delivered to the gas producer under pressure derived from an auxiliary source and the gas generated in the producer is delivered to the engine under the same pressure.

In the suction system, both the passage of the air through the producer and the introduction of the gas generated therein into the cylinder of the engine is effected by the sucking action of the piston during its forward or charging stroke.

Although the pressure producer is usually composed of more cumbrous apparatus, and requires more space for its installation, it possesses greater elasticity than the suction system for meeting variations in fuel conditions and has greater capacity for utilizing different kinds and cheaper grades of fuel. It is undoubtedly the better for use in connection with large power units, and in cases where several gas engines are operated from the same producer plant.

On the other hand, for isolated plants of small capacity, or where only a single gas engine of medium power is used intermittently, the application of

FIG. 541.—Syracuse gas producer. ***It consists of*** a shell lined with fire brick and containing a hot, deep fire. An opening near the bottom lets in a mixture of air and steam and an opening near the top takes off the gas. The gas may be *drawn off*, causing a flow of air and steam into the bottom as in the suction type, or the air and steam may be *blown in*, causing the gas to flow off as in the pressure type. All the other parts of a producer such as charging hopper, grate, ash pit, steam generator, purge valve, scrubbers, etc., are auxiliary to the above. ***In operation,*** a fire is built as in an ordinary furnace, the draught being furnished by a blower or exhauster operated by hand or power. After the fire is well started, steam is mixed with the entering air and soon a combustible gas is being generated. When the gas burns well at a test cock near the engine, the blower or exhauster is stopped and the engine started. The generation of gas now proceeds automatically by the drawing in of the air and steam through the fuel bed and the resulting gas through the balance of the system, as a result of the suction caused by the engine. ***The scrubbers,*** cool and clean the gas. In the suction plant the gas is taken from the latter into the engine cylinder and no storage is necessary. Upon each suction stroke of the engine, gas is drawn into the cylinder and off the top of the producer, air and steam entering at the bottom to take its place.

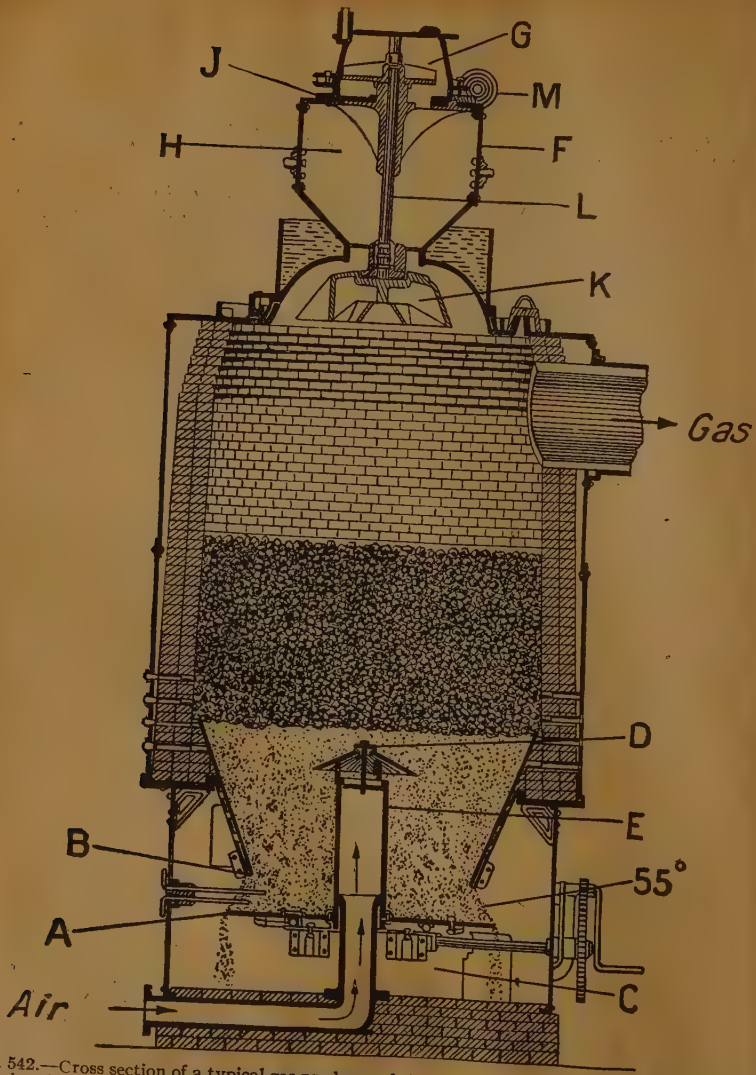


FIG. 542.—Cross section of a typical gas producer of the pressure type using anthracite coal, as described in the accompanying text.

the suction system not only enables the simplification of matters relative to bulk and the reduction of cost, but it affords the more important advantage of making the demand of the engine for gas the controlling factor in the generation of the gas from the solid fuel.

How a Producer Operates.—Fig. 542 shows a section of a typical producer of the pressure type using anthracite coal. The incandescent fuel is supported upon a bed of ash, this resting on a revolving table, A, which is larger in diameter than the bosh, B, the ashes forming a natural slope of about 55°. As they are formed, the ashes fall into the sealed ash pit, C.

In regular operation, the line between the ashes and fuel is kept about six inches above the cap D, of the central air pipe E, so that the fire comes into contact with the brick lining only, all iron work being kept away from the heat. This height is maintained constant by grinding or revolving the ash table once every 6 to 24 hours according to the rate of working.

The blast is usually furnished by a steam jet blower, but a fan blower may be used if more convenient, a small steam pipe being run into the vertical air pipe to supply the steam required for softening the clinkers and maintaining the proper temperature of the producer. This producer is equipped with a continuous *automatic feed device* F, which consists of a *receiving hopper* G, surmounting the main *storage magazine* H, the communication between the two being regulated by a horizontal *rotary register* J, operated by a lever. The *distributor plate* K, is suspended below the main magazine, and is supported by a steel shaft L, which passes upward through the storage cylinder. Both the hood of the distributor plate and the inverted conical base of the magazine are water cooled, thus facilitating the discharge of strongly caking coals. The receiving hopper is rotated by means of a worm wheel and worm attached to the upper end of the shaft, and the distributor plate is revolved through the radial arms and hub of the receiving hopper, which are also keyed to the shaft. A *hand wheel nut* on the threaded end of the axis affords the means for adjusting the distance between the distributor plate and the coal reservoir. This adjustment, together with the variable speed secured by means of the step cone pulley M, permits of a ready control of the rate of coal discharge.

Pressure Gas Producer System.—As shown in fig. 543 a pressure gas producer system usually consists of the following parts:

A small steam *boiler*, A, for making steam and producing the necessary air pressure; a gas *producer*, B, equipped with a continuous feed arrangement; an *economizer*, C, with *superheater*

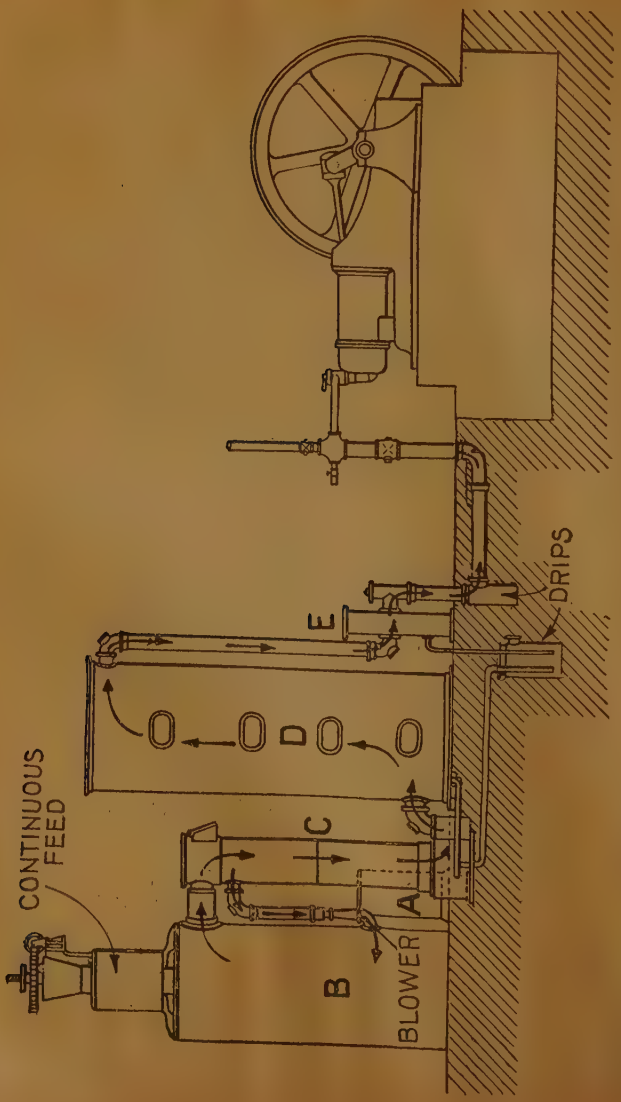


FIG. 543.—Pressure gas producer system.

and *wash box* a *scrubber*, D, a *purifier* E. The details of the several parts may be considerably modified to suit varying conditions.

FIG. 544.—Syracuse regulator. It supplies water to the vaporizer in proportion to the load on the engine. There are no moving parts and all passages may be quickly inspected or cleaned when necessary. Pipe B, supplies water and pipe A, carries off the excess not taken by the regulator. Pipe C, is connected to the engine gas supply pipe and pipe D, leads to the producer. When the engine is idle the water stands at M, but when the engine is drawing gas it rises due to the suction to some point O. The water runs out of the slot shown and through pipe D, to the producer. The amount of this water is proportional to the load on the engine.

For instance, the boiler may be omitted in cases where steam is procurable from any other convenient source, or, in some cases, the separate steam generator may be absolutely unnecessary.

For smaller equipments, or those suitable for operating engines ranging in power up to 500 horse, single producers are considered sufficient.

Larger equipments should be provided with two or more producers, the general design and arrangement of which may be varied to suit the local conditions.

In operation, the gases generated in the producer enter the superheater and economizer. In the economizer the air blast of the producer travels in a direction opposite to that of the blower, and the gas passing through the wash box deposits a large portion of its extraneous suspended matter. Here also is located the seal or non-return against the gases stored in the holder and present in the other parts of the system.

From the wash box the gas enters the scrubber, in which it travels against sprays of water through compartments filled with coke and is still further purified by the removal of any tarry substances, sulphur, or ammonia which it might contain, prior to its introduction into the purifier where the purifying operation is completed.

From the purifier the gas passes into the holder which stores up a supply sufficient for starting and for running several minutes, its chief purpose being the regulation of pressure and variations in the consumption and mixture of gases.

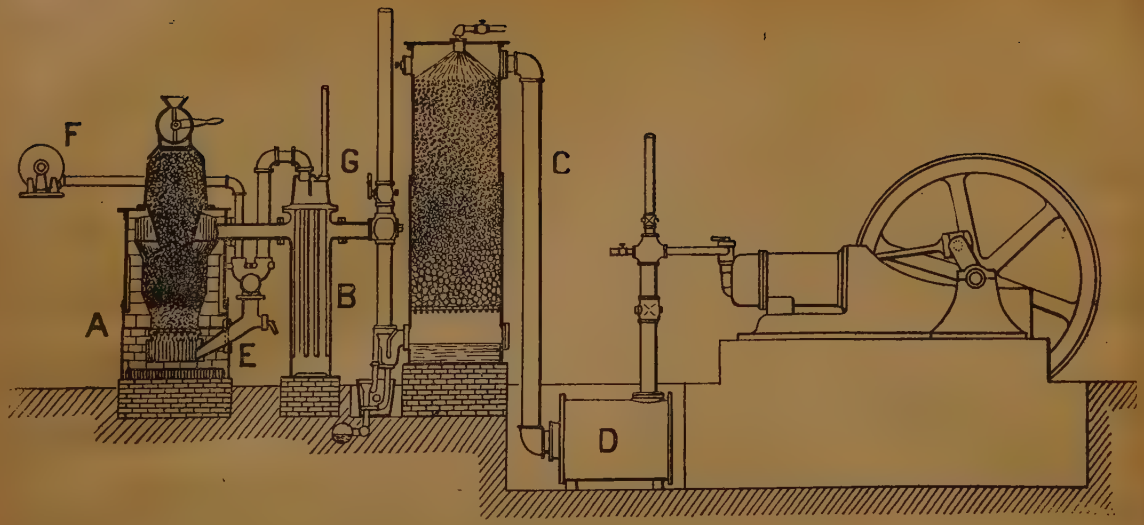
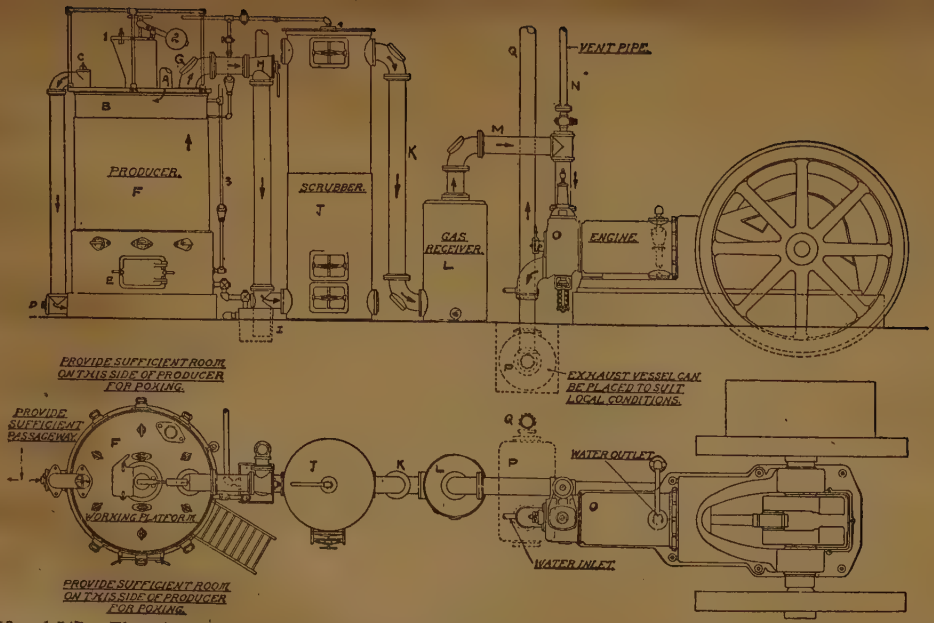


FIG. 545.—Suction gas producer system.

Suction Gas Producer System.—The operation of a suction gas producer system depends upon the sucking action of the engine piston during its forward or charging strokes, which action tends to draw the air supply through the fuel bed of the producer, and the gas generated into the engine cylinder.

In fig. 545, which shows the general arrangement of the various adjuncts of a suction



FIGS. 546 and 547.—Elevation and plan of Otto suction gas producer plant. ***It consists of,*** the producer proper F, scrubber J, gas receiver L, and engine O, all connected by piping. ***In operation,*** the piston of the engine moving outwards creates a partial vacuum in the entire gas making apparatus and sucks air into the producer through inlet A. The air passes through the vaporizer B, where it is enriched with water vapor, then through pipes C and D, to the ash pit E. At point C there is an opening through which dry air can be admitted to the mixture going into the ash pit. From the ash pit E, the air is drawn up through the fire F, then through pipe G, three way cock H, and water seal I, to the scrubber J. From the scrubber it passes through pipe K, to bottom of gas receiver L, then out the top through pipe M, to the engine cylinder O. Pipe N, is a vent pipe which is used as an outlet for the gas just before the engine is started. The gas reaching the engine is drawn into the cylinder, where it is mixed with air, which is also drawn in by the suction of the piston. On the next inward stroke of the piston the mixture is compressed and then ignited by an electric

FIGS. 546 and 547.—*Text continued.*

spark. This burning mixture then expands and forces the piston outward on the power stroke. Again moving inward, the piston forces the burnt gases out into the exhaust vessel P, and then to the atmosphere through pipe Q. *In charging*, coal is put in through a charging hopper shown in the illustration at (1). This hopper is closed to the producer while being filled with coal, then is closed to the atmosphere by an air tight door, while the coal is admitted to the fire pot by opening a seal worked lever by (2.) The producer is a heavy steel jacket, provided at the bottom with grates, and lined with fire brick. Resting at the top of the producer is the evaporator B, which is a cast iron water vessel of circular cross section. The use of this water filled evaporator is to keep the top of the producer cool for comfortable working, and to provide the water vapor which is mixed with the air supply, and drawn up through the ash pit and fuel bed. The water vapor is mixed with the air primarily to increase the heat units of the gas by the addition of hydrogen. It also prevents clinkering of the fuel, and keeps the fire cooled down to the proper temperature. The mixture of air and water vapor passes up through the layer of ash's resting directly on the fire grates, into the fire zone where it passes through a fire pot above the grates, until finally we have coming out of the producer at G, a gas containing about 25 per cent. of carbon monoxide, and 16 per cent. of hydrogen which is the real producer of gas. This gas has a heating value of approximately 140 heat units per cubic foot. The hot gas before passing out of the producer passes under and around the water contained in the evaporator B, adding to the heat necessary to produce the water vapor. The gas in going through the scrubber, which is merely a steel cylinder partly filled with coke, is thoroughly cleaned from all impurities and foreign substances. Cool water is constantly sprayed down over the coke by the sprinkler shown at (4) in the illustration, and the gas coming up is forced by the coke to follow a crooked passage, bringing it in close contact with the water. When the engine is stopped the gas from the producer is shut off by a three-way valve H, which simultaneously opens the connection to the smoke pipe and the atmosphere. The fire is then kept alive by the natural draught, and the process of gas making can be resumed within a short time by a blower, provided for the purpose of starting or reviving the fire. The pressure in every part of the apparatus, while the engine is running, is always below that of the atmosphere; consequently, no leaks of gas to the outside are possible. A new fire requires about thirty minutes' blowing, while after a shut down over night, ten minutes' blowing is sufficient to produce gas of proper quality for starting the engine.

system, A, represents the *pro*
ducer; B, the *evaporator;* C, th
scrubber; and D, the *receive*
The operation of the syste
may be described as follows

The gases generated in the pro
ducer pass through the evaporato
which is practically a small multi
tubular boiler, and furnish the sens
ble heat required for evaporating th
water. The resultant vapor is con
ducted to the ash pit of the produce
through the pipe E, by the suckin
effect in the producer, while the ga
passes from the evaporator to th
scrubber filled with coke.

As the gas rises through the inter
stices of the coke, the washing wate
descends and not only takes up an
removes the dust brought over by
the gas, but also clears it of ammonia
and other impurities which have a
tendency to combine readily with
water. From the scrubber the gas
passes to the receiver or *suction box*

The diameter of the receiver being
relatively much larger than that o
the suction pipe of the engine, the
strokes of the engine piston do not
therefore cause pulsations between
the receiver and the producer.

The producer is usually provided
with a charging hopper capable o
holding enough fuel for several
hours' operation, in the smaller sizes
and allows the admission of fuel to
the combustion chamber without
permitting access of air thereto dur
ing the charging operation.

In operating, a fire is kindled upon
the grate, the fuel bed built thereon

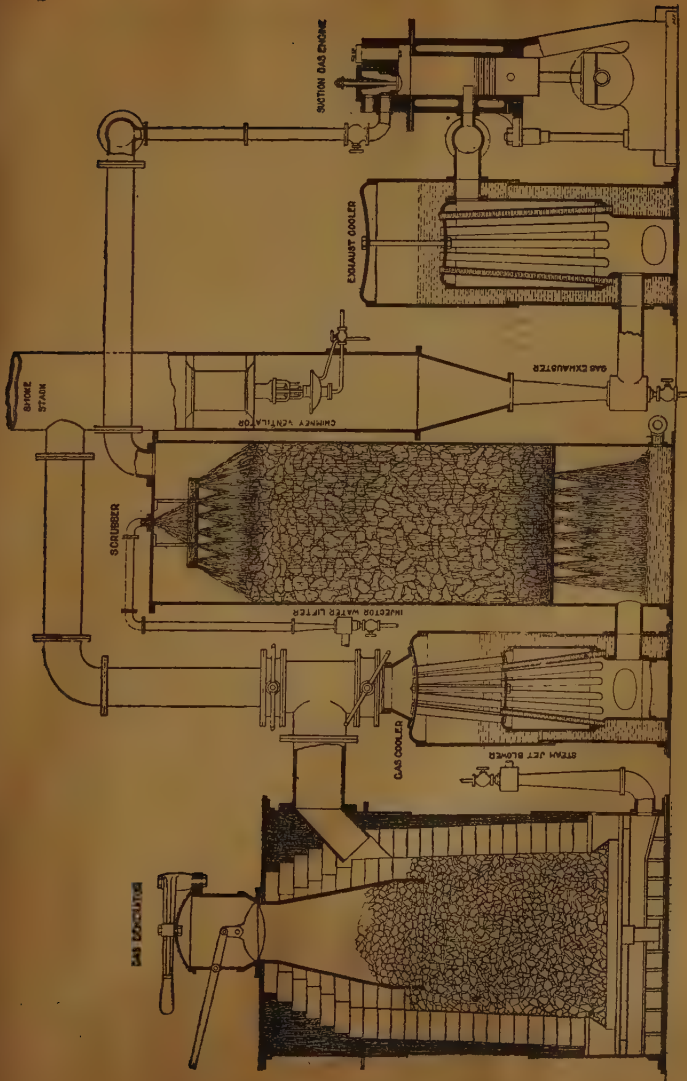
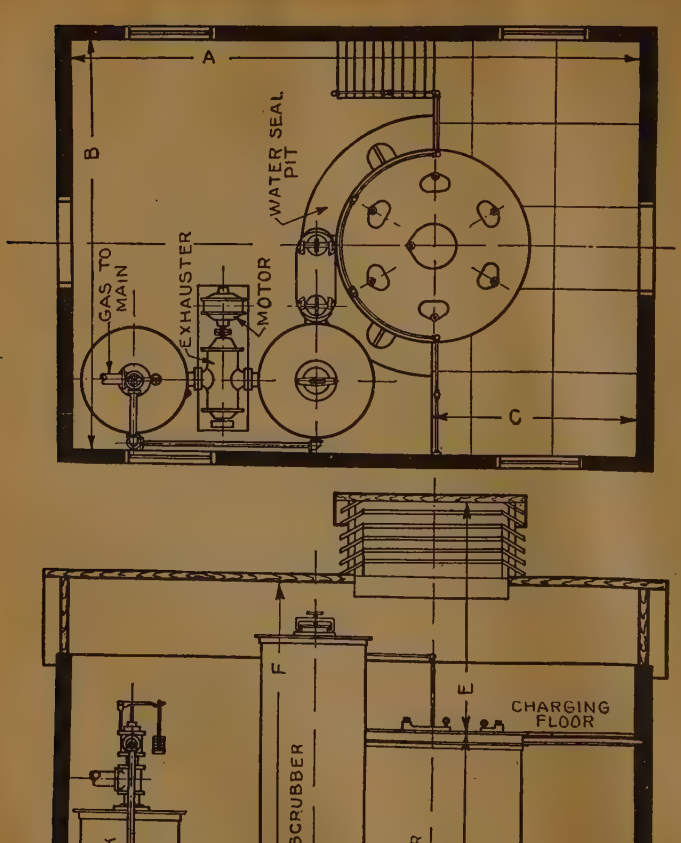


FIG. 548.—Diagram of Marine gas producer and engine plant.



FIGS. 549 and 550.—Plan and elevation of Standard Akerlund suction down draught (type B) producer showing space required. The letters refer to the accompanying table.

and the air necessary for starting combustion supplied by means of a hand or belt-driven *fan*, F. The poor and lean gas produced at starting is first allowed to escape into the open air through the *vent pipe*, G, until the test cock shows that good gas is being produced. The pipe, G, is then closed and the scrubber and receiver are brought into the gas circuit. The engine is now put in operation and as it thereafter performs the function of the fan, the latter is stopped, the operation of the entire system becoming automatic.

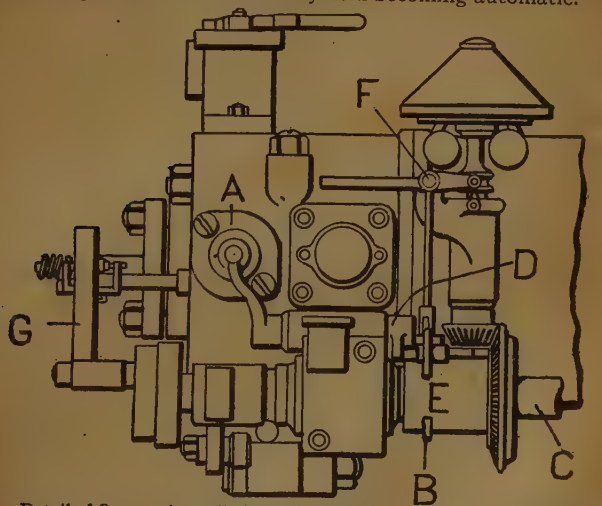


FIG. 551.— Detail of Otto engine cylinder, valve gear side. ***In operation,*** when gasoline is used, it is delivered by the gasoline pump driven by an eccentric on the side shaft, into the stand pipe, from which it gravitates to the gasoline valve A, which regulates the quantity of gasoline and the time of its admission, so as to supply automatically the proper mixture of air and gas according to the requirements of the varying load. The valve A, is operated by the cam B, on the side shaft C, the cam actuating a rocker shaft D, the lower arm of which is fitted with a long pin which carries the gasoline roller E. This roller has a free lateral movement which is governed by the vertical arm of the bell crank F, connected with the governor a very slight movement of which is sufficient to place the roller in or out of engagement with the cam on the shaft. The speed of the engine is regulated by the governor which changes the position of the gasoline roller, so that the fuel is admitted only when the speed is normal or slightly below it. The governor is of the fly ball weighted type. Ignition is effected by an electric spark, the igniter being operated by the igniter lever G, actuated by the side shaft. The electrodes of the igniter are tipped with platinum, and the current is derived from a primary battery.

Producer Gas Engines.—It should be noted that engines which have been designed to operate on gasoline fuel require modification before they will be suitable for operation on producer gas. First the valve areas will have to be larger, due to the necessity of taking in large quantities of a weaker gas, and

second, a higher compression will be necessary and advisable for best economy. Compressor pressures according to Durand of from 150 to 180 lbs. should be used.

Rated Capacity of Standard Sizes and Space Required

Akerlund Type B Gas Producers

No.	Rated Capacity		Space Required					
	Horse Power	Coal per hour (lbs)	A	B	C	D	E	F
2	25	40	18′-0″	12′-9″	6′-3″	10′-6″	12′-0″	17′-0″
5	50	75	19′-9″	13′-9″	6′-9″	10′-6″	12′-0″	17′-0″
7	75	115	21′-0″	14′-6″	7′-3″	10′-6″	12′-0″	17′-0″
10	100	150	22′-0″	15′-0″	7′-6″	10′-6″	12′-0″	17′-0″
15	150	225	23′-3″	16′-0″	8′-0″	10′-6″	12′-0″	17′-0″
20	200	300	25′-0″	17′-0″	8′-6″	11′-6″	12′-6″	18′-0″
25	250	375	26′-0″	17′-9″	8′-9″	11′-6″	12′-6″	18′-0″
30	300	450	28′-0″	18′-6″	9′-3″	11′-6″	12′-6″	18′-0″
35	350	525	28′-6″	19′-0″	9′-6″	11′-6″	12′-6″	18′-0″
40	400	600	30′-3″	20′-0″	10′-0″	12′-6″	13′-6″	18′-0″
50	500	750	33′-0″	21′-3″	10′-6″	12′-6″	13′-6″	20′-0″
75	750	1125	36′-9″	22′-9″	11′-6″	14′-0″	14′-6″	22′-0″
100	1000	1500	42′-3″	24′-3″	12′-3″	15′-0″	14′-6″	24′-0″

NOTE.—***Mechanical scrubbers.*** The objection to mechanical scrubbing is that it is not positive. A producer depending upon mechancial apparatus for delivering clean gas ceases to deliver clean gas as soon as the mechanical parts become inefficient. Inefficiency will result from reduction in speed or failure to clean out the apparatus at the proper time. Granting that the mechanical scrubber will deliver clean gas when in perfect condition (which has not been proved in actual practice with all fuels), it is perfectly clear that such apparatus is liable to become ineffective at times due to the slipping of a belt, the burning of a fuse, failure in water supply, clogging of moving parts, or any one of the minor mishaps which may occur in the course of actual operation. Whenever this happens, dirty gas goes over to the engine or to the pipe connections and causes the troubles which the mechanical scrubber is supposed to prevent. As recovered from the mechanical scrubber, tar seldom has a market value as a by-product, and, even in the rare cases where there is a demand for marketable tar at a profitable price, the tar removed from the gas usually has to be treated before it can be sold. Therefore, mechanical scrubbing equipment for bituminous fuel cannot be considered reliable or effective. Moreover, the power required for driving the mechanical scrubber is excessive and this reduces the overall efficiency of the plant.—*Standard Co.*

NOTE.—***Double zone producers.*** Machines of the double zone type, or those which introduce draft from above and from below, must confine themselves to a limited field, because they cannot be recommended for simplicity and ease of operation, and because there are many fuels which will not behave properly in this type of apparatus. There is no way for the operator to tell which zone is doing the work. When the upper zone cools off, or when the fire drops to a lower level, tar goes over with the gas and the producer becomes for all practical purposes a simple updraft producer. The labor of operation is hard, skilled labor is required, and the equipment is both cumbersome and expensive.

CHAPTER THIRTY-FOUR

DIESEL ENGINES

Rudolph Diesel, a German engineer, aiming to increase the efficiency of internal combustion engines, found from purely theoretical consideration that the highest efficiency would be realized by carrying out in practice the ideal Carnot cycle.*

To approximate as nearly as possible to this cycle Diesel devised a cycle, the unique features of which he describes in his treatise "The Rational Heat Motor," as follows:

"The characteristics of the working cycle, as deduced from one theory of combustion are:

"1. Production of the highest temperature of the cycle, not by and during combustion, but before and independently of it, solely by compression of air, or of a mixture of air and gas.

"2. Gradual introduction of the pulverized combustible into the compressed and heated air during part of the stroke of the piston, and in such a way that combustion produces no increase in temperature of the gases. Hence the combustion curve obtained is as nearly as possible isothermal. After ignition, combustion is not left to itself, but is regulated by external mechanism throughout its course, and the right proportions are thus established between the pressures, volumes and temperatures of the gases.

"3. Choice of the right weight of air in proportion to the heat value of the combustible, the temperature of compression (and of combustion) being previously so determined that the working of the engine, lubrication, etc., can be carried out without cooling the cylinder.

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*NOTE.—***In the Carnot cycle,** a working fluid at a given temperature and volume expands while doing work and receiving heat sufficient to maintain it at constant temperature. When the addition of heat ceases the expansion continues adiabatically, the temperature falling to the lowest point of the cycle. During the return, heat is withdrawn in proportion to the reduction in volume, and the curve is again isothermal. The compression is adiabatic, and in the true Carnot cycle the gas is returned to its original volume and temperature.

"We need scarcely say that, in practice, these conditions can hardly be realized. In working engines the corners of the indicator diagrams are more or less rounded, the curve of combustion is not perfectly isothermal and under given conditions a certain increase in temperature or pressure will be caused by combustion. This rise, however, is slight in comparison, with that previously produced in the temperature and pressure of the gases by compression. Nor do these differences affect the principle of the cycle."

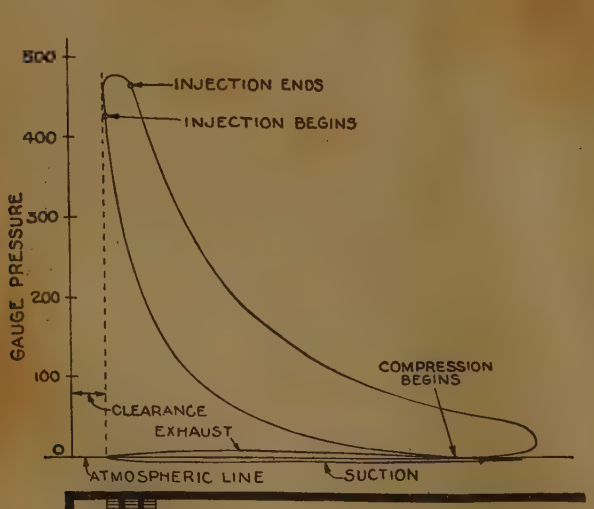
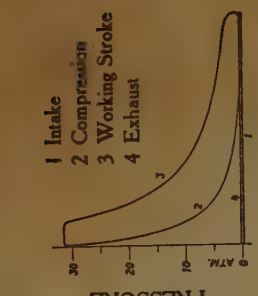


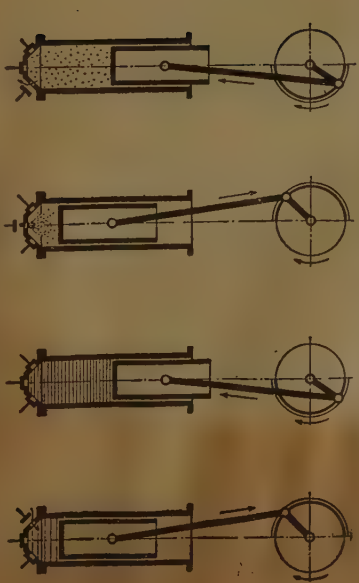
FIG. 552.—Typical indicator card of Diesel four cycle engine. It will be noted from the diagram that the pressure range and mean effective pressure is much greater than in other engines which accounts for the massive construction.

The Diesel cycle may be completed in either two or four strokes, the latter being the prevailing practice. Briefly the four stroke Diesel cycle is as follows:

Suction Stroke.—Admission of air into the cylinder.

Compression Stroke.—Compression of the charge of air to about 500 lbs. pressure which causes its temperature to rise to about 1,000 Fahr.





FIGS. 553 to 557.—The four strokes of the Diesel four-stroke cycle and theoretical diagram showing usual working pressure.

As this pressure is reached gradually it does not cause a shock to the engine, such as an explosion to the same pressure would give.

Power Stroke.—At the beginning of the stroke, oil previously delivered to the injector valve is blown into the cylinder in the form of fine spray by a small quantity of air compressed by a special compressor to 700 or more lbs. pressure.

The oil spray meets the highly heated air in the cylinder, ignites and burns; combustion continues so long as the fuel is being injected, usually for about one-tenth of the power stroke.

Usually the heat generated by the combustion is not sufficient to prevent the pressure on the cylinder falling while admission is taking place, so that the admission line on the indicator card falls below the constant pressure line as seen in the indicator card, fig. 557.

Exhaust Stroke.—Expulsion of the products of combustion from the cylinder, thus completing the cycle.

The exhaust valve usually begins to open at between 80 per cent. and 90 per cent. of the expansion stroke. During the establishment of pressure equilibrium, the velocity of the gases is very great.

The Diesel engine then, from the foregoing summary of its

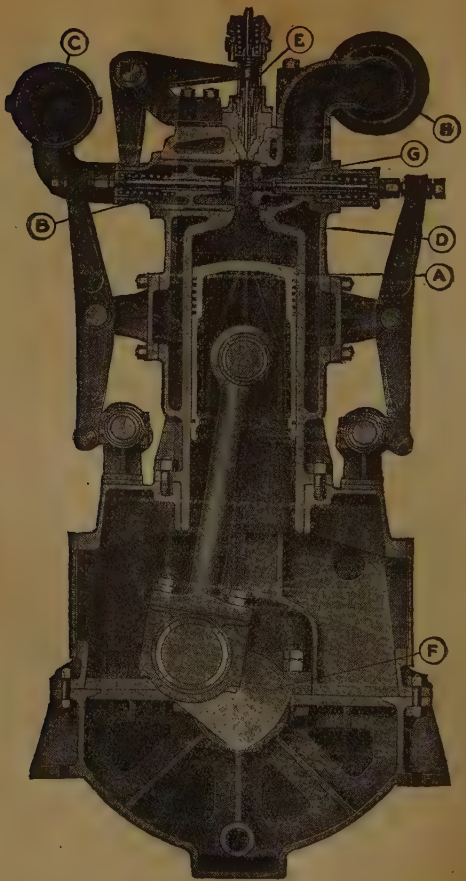


FIG. 558.—Cross section of Nelseco Diesel engine. A, piston; B, intake valve; C, intake manifold; D, cylinder; E, fuel valve; F, crank shaft; G, exhaust valve; H, exhaust manifold cylinders 9 × 12½. There is an air compressor for supplying air for injecting fuel and for starting purposes, provision being made on two cylinders for air starting. The compressor is of the two stage tandem type, and provision is made for regulating pressure carried on spray air by means of throttle on first stage suction. The bed plate is in one piece, of cast iron, and is enclosed to catch all oil draining from bearings. Flanges are provided for bolting to foundation and housing. Cross girders are provided for main bearings for crank shaft. These have cast iron shells lined with white metal, with semi-circular lower brasses so that they may be rolled out after removing weight of crank shaft. The bed plate is extended aft to take reverse clutch and thrust bearing. The housing is in one piece of cast iron of rigid design and bolted directly to bed plate. Large openings are provided on both

working cycle, may be defined as *a high compression, four (or two) cycle combined pump and compressed air injection oil engine*, and the essential elements necessary for the practical working of the cycle are:

1. Water cooled cylinder with inlet, exhaust and fuel valves.
2. Fuel pump.
3. Sprayer or pulverizer.

FIG. 558.—*Text continued.*

sides for access to crank pit. To top of housing are bolted working and compressor cylinders and cam shaft bearings. The crank shaft is of forged steel in one piece. The connecting rods are of forged steel, with solid wrist pin ends fitted with phosphor bronze bushings and tee head crank ends for bolting to crank pin boxes. The crank pin boxes are of cast steel lined with white metal. The wrist pins are steel forgings, hardened and ground and secured in pistons. The pistons are of cast iron of trunk type and fitted with cast iron snap rings to retain compression. The working cylinders are of cast iron, with water jacketed barrels and heads. The cylinder heads are cast integral with barrel and contain the valves. Each cylinder has an inlet and a relief valve on the front of the engine, a spray valve on top, and an exhaust valve on the back. The inlet valve is of forged steel and carried in a separate cage. The exhaust valve has a steel stem with cast iron head of special design to withstand action of exhaust gases. The spray valve has a steel needle with atomizer and cage of special design. The two cam shafts, carried in white metal lined cast iron bearings on top of housing, are driven from crank shaft by spur gears on after end of the engine. The cam shaft on back of engine operates exhaust valves by rocker levers. The cam shaft on front of engine operates inlet valve by rocker levers and spray valves by rocker and bell crank levers. Two cylinders are fitted with air starting valves operated from front cam shaft. The gear of those valves is so arranged that when they are in operation spray valves on these cylinders are cut out, and when spray valves are operating starting valves are cut out. The first and second stage air compressor cylinders are in one piece, of cast iron, water jacketed, and with a separate water jacketed cast iron second stage head. Both first and second stage valves are steel with cone seats, and of the automatic spring controlled type. The air cooler, placed in back of engine opposite compressors, has separate passages for first and second stage air, and has sufficient surface to thoroughly cool air after each stage of compression. A spray air flask is secured to back of engine and is connected into line between compressor and spray valves. Forced lubrication is used for principal bearings, oil being supplied under pressure, by rotary pump, to main bearings and thence passing through holes drilled in crank shaft to crank pins and through connecting rods to wrist pins. All surplus oil drains back to crank pit, is filtered and used over again. The crank case is oil tight to prevent leakage of oil outside. The cylinders are supplied from a positive feed mechanical oiler. Cam shaft and other bearings, except those subject to very little motion and oiled by hand, are fitted with grease cups. The fly wheel is bolted to a flange on forward end of shaft. There is a flange at the after end of shaft bolting to reverse clutch shaft. The fuel system consists of a pump located at forward end of engine and driven from front cam shaft extended, with a separate plunger, for each cylinder. Fuel is supplied to pump from the gravity tank, which is divided into two parts with a filter between, so that no foreign matter can get to fuel pumps. The discharge from each individual fuel pump leads to its respective spray valve. The speed of engine is controlled by amount of fuel supplied to cylinders, which in turn is controlled by timing of individual pump suction valve. A governor driven from back cam shaft is located at forward end of engine and controls engine speed by holding open fuel pump suction valves. The intake manifold, forming inlet muffler, runs along front of engine and working and compressor cylinders take air through it. The exhaust manifold runs along back of engine, is secured to tops of cylinders, and is of cast iron and water jacketed. The exhaust muffler is of cast iron of sufficient capacity and of suitable design to effectually silence exhaust. The reverse gear is of heavy duty mechanical type, with friction discs for ahead motion and spur gears and band clutch for astern motion. The thrust bearing has white metal bearing surface of ample area. The cooling water pump is of plunger type, mounted on gear case, and driven from intermediate gear, and is of ample capacity to keep engine cool under all conditions.

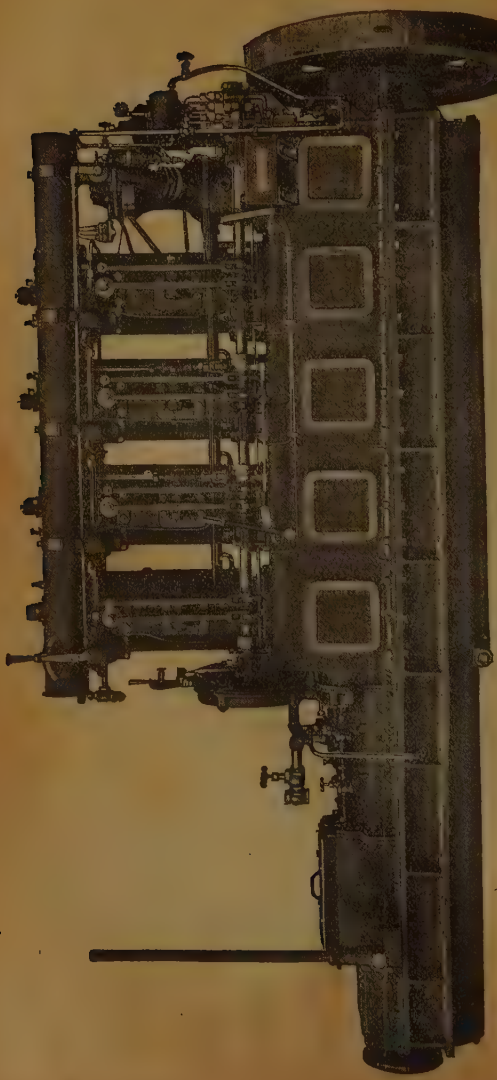


FIG. 559.—Nelseco Diesel four cycle reversing gear type marine engine (intake side), built in 120, 180 and 240 horse power sizes.

4. Air compressor.

5. Valve gear and connections.

The Cylinder. —The usual jacketed cylinder is employed in the Diesel engine, though it is somewhat larger than the ordinary cylinder to accommodate the extended piston. The cylinder head, which is also water jacketed, covers the inlet valve, exhaust valve, air starting valve, and fuel sprayer.

Sprayer or Pulverizer. — The efficiency of the engine depends largely upon the effectiveness with which this device atomizes the fuel, as for proper combustion, the fuel must be injected into the cylinder in a very finely divided state.

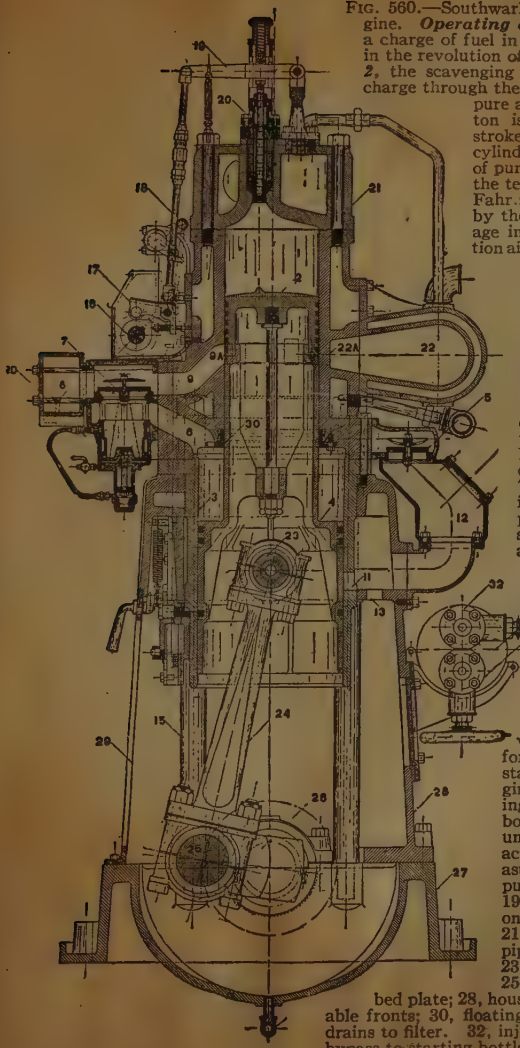


FIG. 560.—Southwark-Harris two cycle Diesel engine. ***Operating cycle: 1,*** the fuel pump injects a charge of fuel in the atomizer at a certain time in the revolution of the engine and leaves it there; ***2,*** the scavenging pump blows out the previous charge through the exhaust and leaves a charge of pure air in the cylinder when the piston is at the end of the outward stroke; ***3,*** the piston returns in the cylinder and compresses this charge of pure air to about 500 lbs. pressure, the temperature rising to about 1,000° Fahr.; ***4,*** the atomizer spindle is lifted by the cam shaft, opening the passage into the cylinder, and the injection air forces the oil, lying in the atomizer, into the hot charge in the form of a spray The oil immediately ignites and further heats the air, and causes same to expand behind the piston and thereby transmit power to the crank shaft. There is no explosion in either this or the four cycle type of engine, the pressure does not materially exceed the compression pressure, but owing to the additional heat supplied by the burning of the fuel, the expansion creates the power. The parts are: 1, main or working cylinder; 2, main or working piston; 3, scavenging and air starting cylinder; 4, scavenging and air starting piston; 5, scavenging air inlet valve; 6, scavenging air outlet passage, starting air inlet passage; 7, scavenging air delivery valve; 8, scavenging air manifold between adjacent cylinders; 9, scavenging air inlet to working cylinder; 9A, scavenging air inlet ports; 10, air operated intercepting valve for air starting; 11, outlet for starting air; 12, silencer for starting air exhaust and scavenging air inlet; 13, vents for housing fumes; 14, injection air storage bottle; 15, removable front columns; 16, cam shaft; 17, atomizer actuating rockers (one ahead, one astern); 18, radius or atomizer push rods (one ahead, one astern); 19, atomizer levers (one ahead, one astern); 20, atomizer spindle; 21, cylinder head; 22, exhaust pipe; 22A, exhaust outlet ports; 23, wrist pin; 24, connecting rod; 25, crank pin; 26, crank shaft; 27, bed plate; 28, housing; 29, light sheet steel removable fronts; 30, floating packing rings; 31, crank pin drains to filter. 32, injection air from compressor; 33, bypass to starting bottles.

There are various types of sprayer and much time has been given to the development of this part as it is a vital element of the engine.

Starting Valve.—The engine is started by compressed air from an auxiliary reservoir, a special starting valve being used for the purpose.

Air Compressor.—For the operation of a Diesel engine a supply of air compressed to from 700 to 1,000 or more pounds pressure is necessary. This high pressure puts severe duty on the compressor and accordingly it is an important part of the engine.

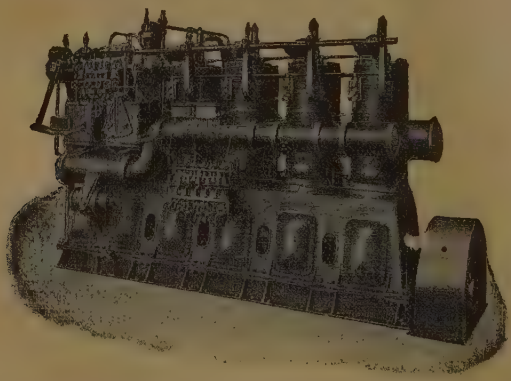


FIG. 561.—McIntosh & Seymour two cycle reversible Diesel engine of 400 brake horse power.

In medium size engines a two stage compressor is generally used, and for larger engines the air is compressed in three stages, inter-cooler being provided so as to maintain a moderate temperature, and thus avoid explosions which might result from the lubricating oil.

The compressors are preferably directly connected to the crank shaft of the engine.

Valve Gear.—The general arrangement consists of a long shaft driven from the crank shaft by means of spiral gears. It serves to drive the valve gear, governor, sprayer, and starts lubricating and fuel oil pumps.

Lubrication.—A typical lubricating system consists of a force feed oiler for the cylinders and piston crank shaft bearings.

In one make of vertical engine the crank shaft is drilled through its entire length and a small self-priming rotary pump circulates the oil from the engine bed to all bearings located inside the crank case, and up through the hollow connecting rod to the wrist pin. The oil flows back to the crank chamber where it is filtered and so used over and over again. An overflow valve in the system regulates the amount of pressure, which is normally held at 15 pounds; and a gauge mounted over the force feed lubricator may be readily observed by the operator.

How to Run a Diesel Engine.—In general the attention necessary for properly operating the engine may be briefly stated as follows:

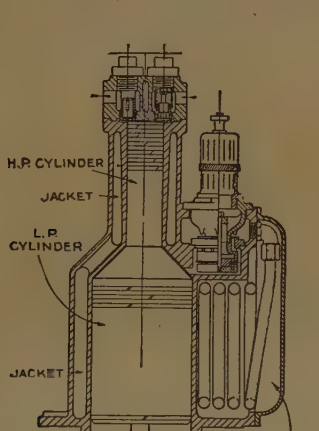
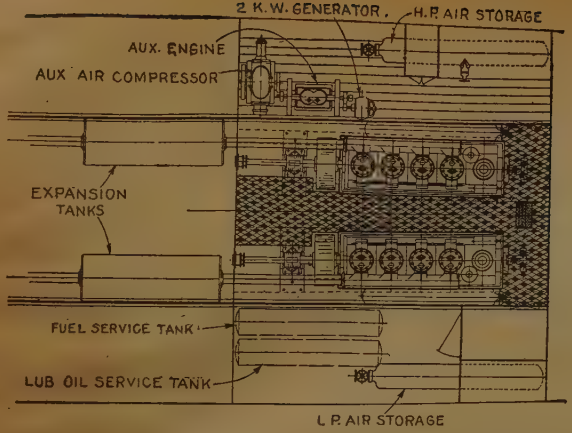
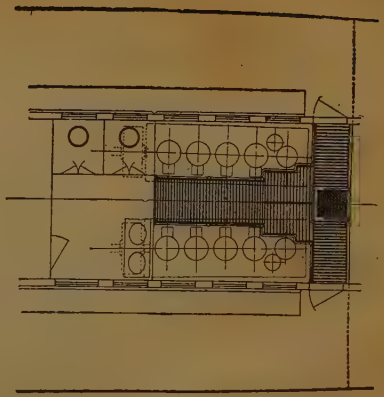


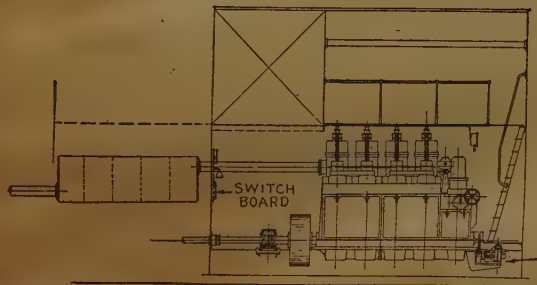
FIG. 562.—Fulton air compressor. It is of the two stage type and is driven directly from the main crank shaft. Free air is drawn into the larger cylinder and compressed to seven or eight atmospheres (approximately 105 to 120 lbs. per sq. in.) after which it is delivered to an inter-cooler before being drawn into the high pressure cylinder, where it is compressed to from 55 to 65 atmospheres (approximately 825 to 975 lbs. per sq. in.); thence to a second cooler, after which it is stored in the small air receiver for fuel injection. The compressor delivers slightly more air than is required for fuel injection and this surplus is stored in the two large receivers for starting. Air in the starting receivers may be at any pressure from 700 to 1,000 lbs. per sq. in., but the injection air should vary with the load, *i. e.*, 800 lbs. for half load, 975 lbs. for full load and slightly higher, say 1,000 lbs. for 10 per cent. overload.

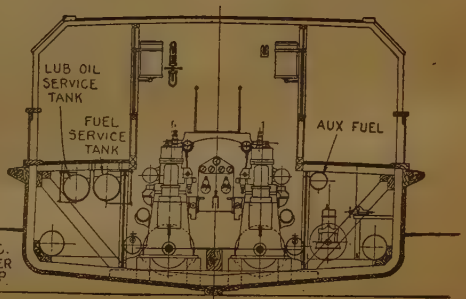
Before Starting.—See that the lubricating system has the proper supply of oil, care being taken that all lubricators are in proper working order.

The cooling water system should be examined, and if necessary the circulating pump primed, and all valves opened for the proper flow of the water. The compressed air in the receiver should be brought up to the proper pressure.









FIGS. 563 to 566.—Installation of two Southwark-Harris two cycle Diesel engines in a shallow draught passenger vessel

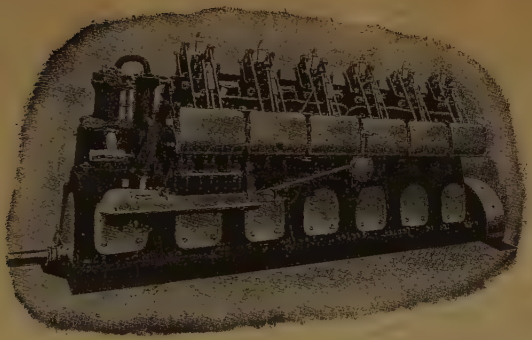


FIG. 567.—McIntosh & Seymour sub-marine type Diesel engine.

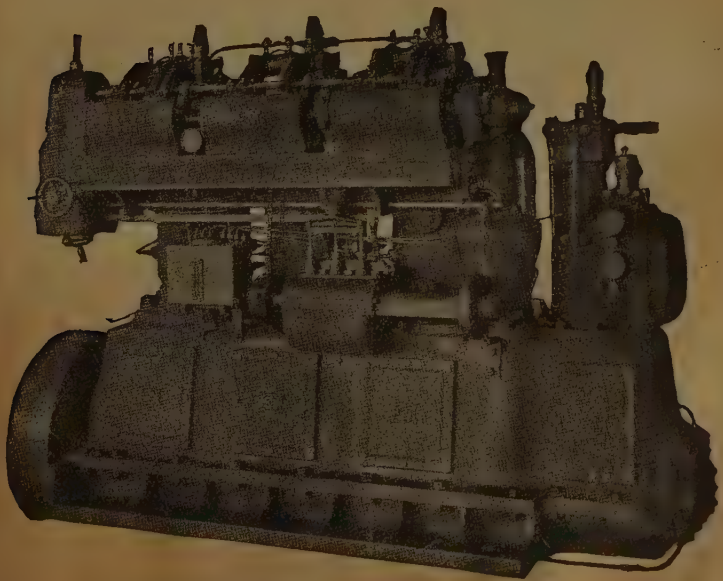


FIG. 568.—Fulton four cycle heavy duty Diesel type engine.

Starting.—If the engine be provided with automatic starting arrangement open the valve on the starting receiver and the valve on the injection air receiver.

When engine comes to speed, put starting valve lever in the off position and shut off receiver containing the starting air, also open fully the injection air valve.

Engines may be started with air at pressure as low as 200 to 300 pounds. If, however, the injection air pressure be below 600 pounds, the valve on the injection air receiver should be closed when the starting air receiver is opened. It can be reopened as soon as the engine has come to speed.

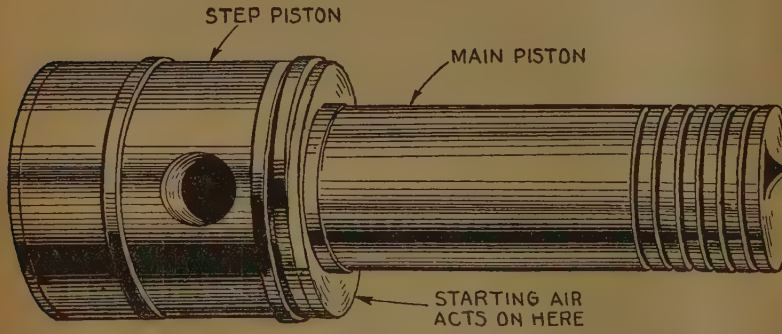
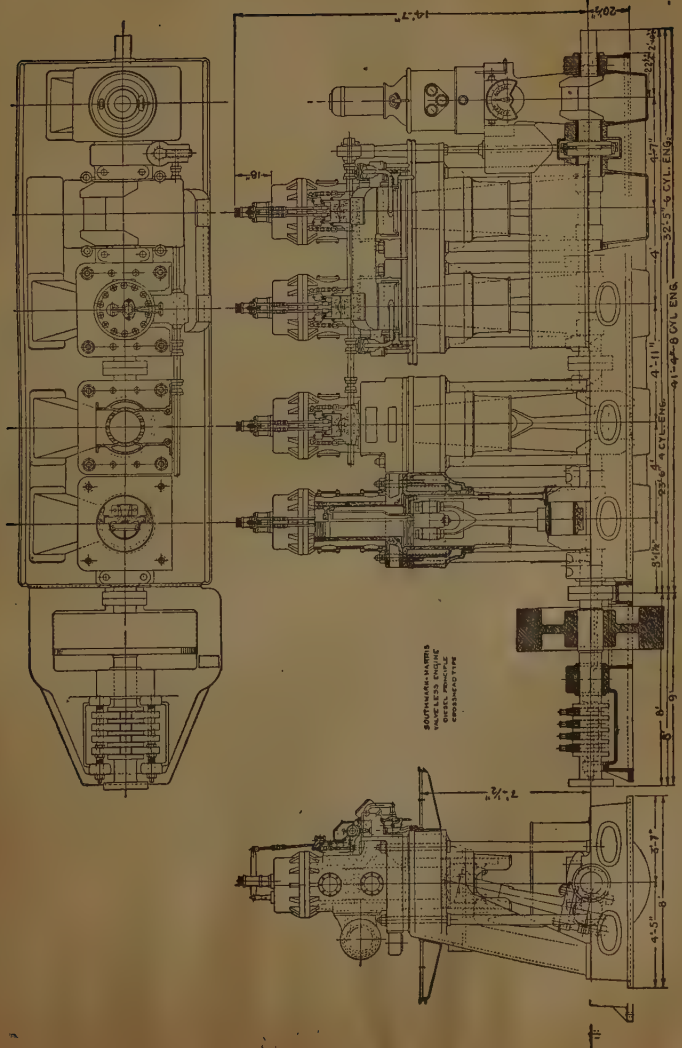


FIG. 569.—Southwark-Harris two cycle Diesel engine step piston. The construction is such that cold starting air is not admitted to the working piston. The step portion of the piston forms the scavenging pump or low pressure compressor. It is while reversing or starting the engine on compressed air that the scavenging cylinder and step piston play a prominent part as follows: Each scavenging cylinder on the movement of the starting lever either *ahead* or *astern* becomes *converted into an air engine* by the automatic cutting out of the suction and delivery valves, the air starting valves automatically come into play with the cam shaft and keep the engine running, owing to the compressed air acting on the step pistons instead of on the main pistons. By the continued movement of the handling lever the atomizers begin to open and the fuel commences to be supplied to the working cylinders, the engine *still running on compressed air in the scavenging cylinder* without having affected the working conditions in the main cylinder, thereby avoiding the admission of the usual high pressure air into the working cylinders, just at the time when it is necessary to build up a temperature. It is not necessary to shut off the fuel, nor interfere with the conditions in the main cylinders at any time when reversing. In starting and reversing the engine, the atomizer *valves do not operate while air starting* until the operator wishes them to do so, and the temperature of the fresh charge of air in the cylinder is quickly raised, owing to the absence of the chilling effect caused by the blast air being allowed to enter through the atomizer valve *without fuel* on each stroke while air starting.

Place engine crank in proper position for starting, exhaust cam on low compression side, and place control handle of starting valve in proper position for starting.

Open air inlet to low pressure side of the air compressor. Pump by hand fuel charge to the sprayer.



FIGS. 570 to 572.—Detail views of Southwark-Harris two cycle Diesel engine, cross head type.

Running.—If light and heavy fuels are used, the heavy fuel can be turne on after starting, being careful if the heavy oil require heating not to admit th heavy fuel until the engine has heated up sufficiently to raise the temperatur of the jacket water to about 110° Fahr.

Stopping.—To stop the engine shut off the fuel supply and close tightly th injection air receiver valve. In freezing weather the jackets should b drained and the cooling air coils between the high pressure air and inter mediate compressor should be blown out as well as the injection pipe.

FIG. 573.—Capt. Roald Amundsen's ship ***"Fram"*** equipped with Swedish marine Diesel engine and used by his expedition when he discovered the South Pole.

Diesel Engine Troubles.—Like all other types of gas engine, the Diesel engine is subject to various troubles, due principally to careless or improper attention from those in charge. The following are those most frequently met with:

FIG. 574.—75 foot tug fitted with Southwark-Harris two cycle Diesel engine of 240 horse power.

Failure to Start.—Usually due to faulty working of starting valves and failure to ignite.

Ignition Fails.—The principal cause is loss of compression. Sometimes the pump does not deliver an adequate charge of fuel, or the timing of the fuel injection may be incorrect.

Pump Fails.—The check valves may be prevented seating by foreign matter in the oil, or the pump may be air bound. The connection and stuffing box must be tight to prevent leakage.

Loss of Compression.—This may occur by leakage, past the piston due to stuck or worn piston rings,

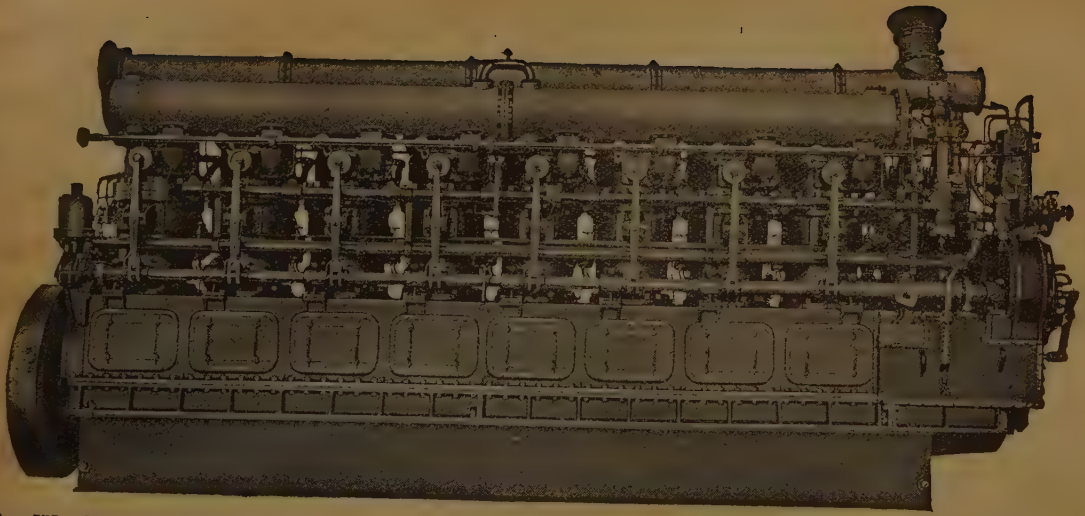


FIG. 575.—Nelseco four cycle marine Diesel engine, direct reversing type (exhaust side), built in 360, 480, 600, 800, and 1,000 horse power sizes.

or past the valve which may need regrinding. Leakage past the exhaust valve may be detected by the color of the exhaust gases; if smoky or black, it indicates that the gases are leaky past the valve resulting in improper combustion. Owing to the very high termperature of the Diesel cycle and leakage past the exhaust valve if allowed to continue will very quickly ruin not only the valve but the valve seat.

Irregular Running.—This may be due to several causes, as fuel injection too early or too late; individual pumps on multi-grade engines not delivering like charges, that is, one pump may deliver more fuel per stroke than the other, due usually to improper action of the check valve or air pockets.

CHAPTER THIRTY-FIVE

REFRIGERATION

Refrigeration may be defined as the process of lowering the temperature of a body or of keeping the temperature below that of the atmosphere. Low temperature may be produced by:

1. A transfer of heat from a warm to a cold body;
2. By expansion of a gas;

If work be done by the gas, as in pushing a piston, this work must be performed at the expense of the energy contained in the gas; the temperature of the gas will therefore fall.

3. Evaporation of liquids having low boiling points.

When a liquid is changed to a vapor, a certain quantity of heat, called the *latent heat of evaporation*, must be added to the liquid to effect the change. When evaporation of a liquid takes place in the presence of other bodies, the heat required for it is drawn from these bodies, and they are thereby cooled.

What may be said of mechanical refrigeration?

Mechanical refrigeration is produced by expanding a heat medium from an ordinary temperature to a low temperature.

What determines the choice of the heat medium?

Its willingness to surrender its heat energy to surrounding objects; vapors are best employed.

How is the vapor treated?

It is compressed and then relieved of its heat in order to diminish its volume. It is then expanded so as to do mechanical work and its temperature is lowered. The absorption of heat at this stage by the vapor in resuming its original condition constitutes the refrigerating effect.

What substances are used for refrigeration?

The most commonly employed agents are ammonia, carbonic acid, sulphur dioxide, and compressed air, the first named being the most generally used and approved, while the others have advantages for use on shipboard and in other places where the fumes of ammonia would prove objectionable.

What are the advantages of ammonia?

It liquefies at low pressure, it is not explosive or inflammable, and possesses great heat absorbing power.

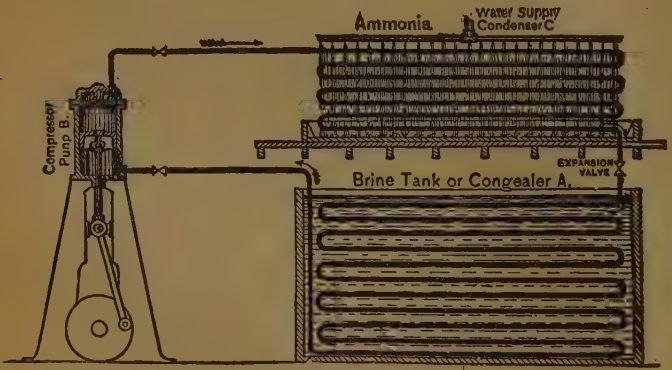


FIG. 576.—Diagram showing the essentials of a mechanical ***compression system*** with vertical compressor. The condenser shown is of the atmospheric type, and the brine circulating system is used, the brine being cooled by the expansion coils in a tank and then circulated through pipes in the refrigerating rooms.

Name two me hods of refrigeration extensively used?

The ammonia compression system, and the ammonia absorption system.

Describe the ammonia compression system.

The ammonia vapor is compressed to about 150 lbs. pressure, and is then allowed to flow into a cooler or surface condenser, where the heat due to the work of compression is withdrawn by the circulating water and the vapor is condensed to a liquid. It is then allowed to pass through an expansion cock and to expand

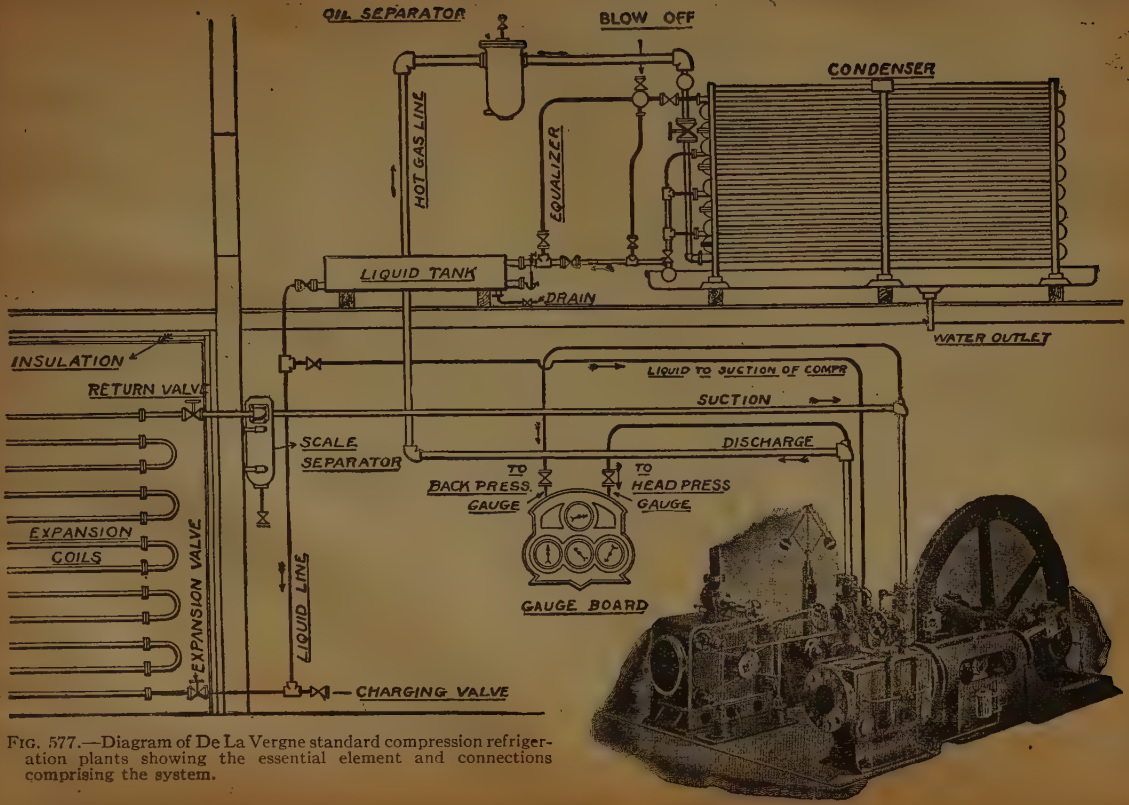


FIG. 577.—Diagram of De La Vergne standard compression refrigeration plants showing the essential element and connections comprising the system.

in the piping, thereby withdrawing heat from the "brine" with which the pipes are surrounded. This brine is then circulated by pumps through coils of piping and produces the refrigerating effect. The expanded ammonia gas is then drawn into the compressor under a suction of from 5 to 20 lbs., thus completing the cycle of operations. The brine consists of a solution of salt in water. Liverpool salt solution weighing 73 lbs. per cu. ft (sp. g. = 1.17) will not congeal at 0° F. American salt brines of the same proportions congeal at 20° F. Ammonia required is

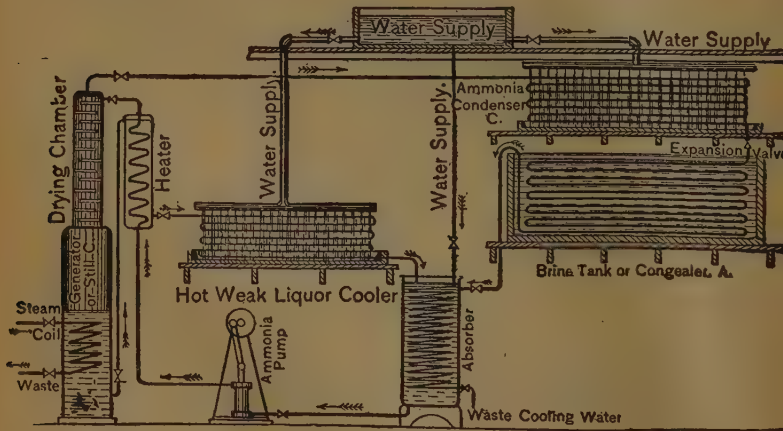


FIG. 578.—Diagram of ***absorption system*** with vertical generator, weak liquor cooler, and brine tank.

.3 lb. per foot of piping. Leakage and waste amount to about 2 lbs. per year per daily ice capacity of one ton. The brine should be about 6° colder than the space it cools

Describe the ammonia absorption system.

In this system the compressor is replaced by a vessel, called the absorber, where the expanded vapor takes advantage of the property of water or a weak ammoniacal liquor to dissolve ammonia gas. (At 59° F. water absorbs 727 times its own volume o

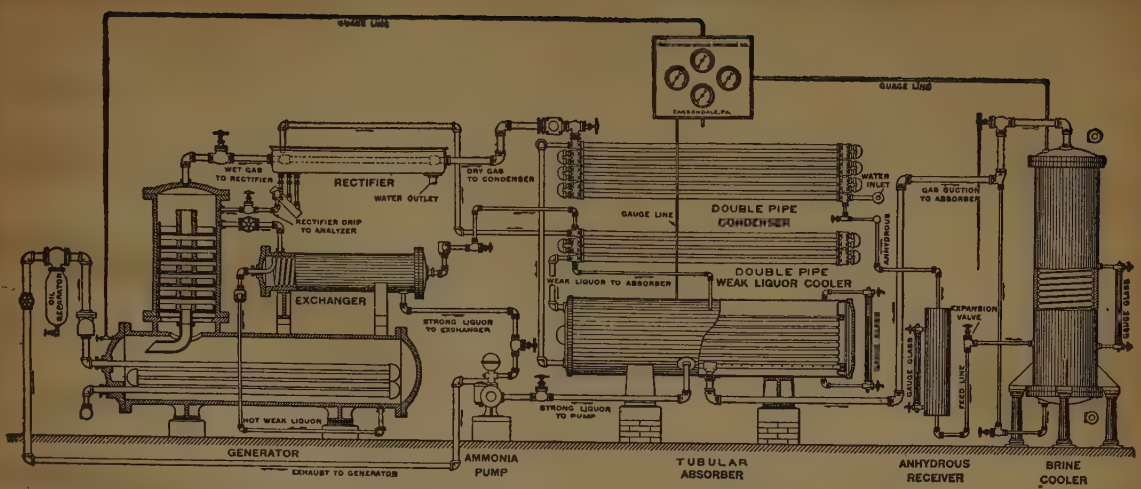


FIG. 579.—Elevation of an ***absorption plant.*** The ammonia is evaporated out of the rich liquor in the generator and analyzer, and passes off into the rectifier; from the rectifier the gas passes to the condenser. The anhydrous ammonia passes from the condenser to the liquid receiver which is simply a reservoir. The receiver is connected to the expansion valve by a pipe of comparatively small size. The expansion valve is regulated so as to allow enough ammonia to enter the cooler to keep the latter at the required temperature. From the cooler the ammonia vapor is led to the absorber into which the poor liquor is sprayed, coming from the exchanger and passing through the weak liquor cooler. The rich liquor is taken from the absorber by the pump and discharged through the exchanger into the analyzer from whence it flows into the generator. The poor liquor is forced by pressure from the generator through the exchanger. In the exchanger the outgoing poor liquor gives up part of its heat to the incoming strong liquor. The brine from the cooler is circulated through the refrigerating coils.

ammonia vapor.) The liquor in the absorber is then pumped into a still heated by steam pipes, where the ammonia gas is vaporized, the remainder of the process being then the same as in the

compression system. The absorption system is less expensive to install, and commercial ammonia hydrate (62% water, sp. g. = 0.88) may be used in the absorber.

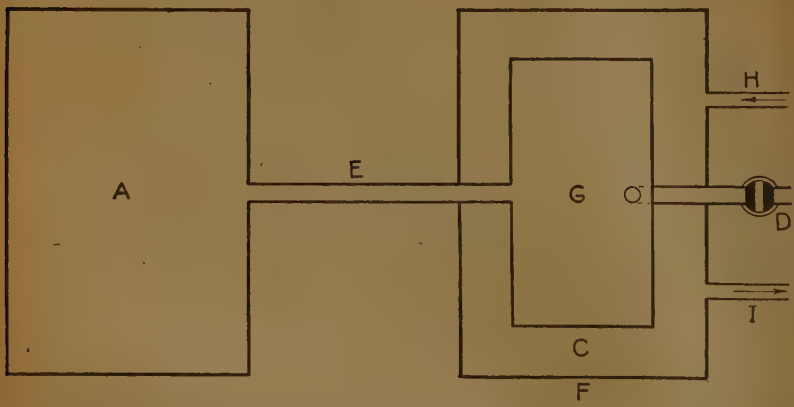


FIG. 580.—Diagram illustrating general principle of the ammonia absorption system. In the figure two vessels, A and G, of proper strength to resist internal pressures of 10 to 15 atmospheres (140 to 220 lbs. per sq. in.), are connected at their tops by a pipe, E. The smaller vessel G, is enclosed within a jacket F, through which and around G, cold water is circulated, entering at H, and leaving at I. The larger vessel A, is partially filled with a strong solution of aqua ammonia and heat is applied as by a fire underneath the vessel A. As the ammonia warms, ammonia gas is driven off and fills G, through the pipe E, air being allowed to escape from the system through a suitable opening in the bottom of G. When ammonia gas begins to issue strongly from this opening, the escape is closed by a cock D, provided for the purpose. Since the volume of gas in solution in the liquor in A, is many times that of the water itself, the continued application of heat drives off such quantities of the gas as to create a constantly increasing pressure in the system. Just as in the case of water, ammonia has for every pressure a corresponding temperature of boiling and of liquefaction, at which temperature ammonia gas will liquefy if heat be abstracted from it, and ammonia liquid will gasify if heat be added to it. If the cooling water have a temperature of 60° F., and maintain the vessel G, and its contents at a temperature of, say, 65° F., it is evident that when the pressure of the gas within G, reaches about 103.33 lbs. per sq. in. by gauge (118.03 lbs. absolute), the further expulsion of gas from the liquor in A, causes a corresponding liquefaction of ammonia in G, and by continuation of the process an accumulation of liquid ammonia results in G, until all the gas has been driven off from the water in A, the pressure remaining constant during the process and the latent heat of liquefaction being carried away by the cooling water flowing out at I. When the distillation of ammonia into G, is completed, the process may be reversed by cooling A. This enables the water in A, to absorb and dissolve the gas in contact with it, creating an immediate flow of gas from G, and causing a reduction of pressure in the system. This decrease of pressure lowers the boiling temperature of the liquid ammonia in G, and consequently it at once starts to gasify. Now as, in liquefying, the ammonia yielded up its latent heat to the cooling water in C, so, in gasifying, heat must be abstracted by the ammonia from its surroundings. Hence, if the flow through C, be stopped, the water remaining around G, will be cooled and ultimately frozen. If then, a brine whose freezing temperature is low, be substituted for the water in C, it may be piped away for cooling storage space or may freeze cans of water immersed within it for ice making purposes.

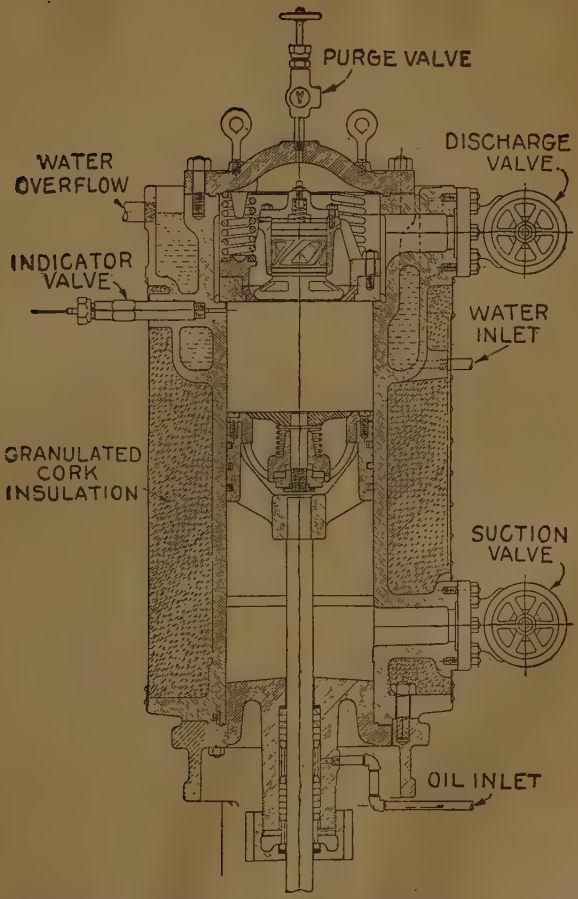


FIG. 581.—Sectional view of York vertical single acting false or safety head ammonia compressor. ***The safety head*** is held on its seat by springs so that in case of breakage of the valves or any other part of the machine, the head lifts and allows the obstruction to pass through or keeps on lifting until it attracts the attention of the engineer. ***The stuffing box*** is designed to permit the piston rod to travel back and forth through a well of oil, situated between the two sets of packing. The lower part of the cylinder is cork jacketed and the upper part water jacketed. ***In operation*** gas enters at the bottom of the compressor and passes up through the balanced suction valve in the piston, is compressed on the upward stroke of the condensing pressure and passes out from the cylinder through the discharge valve in the centre of the safety head.

Name two methods of compressing.

Dry compression and wet compression.

What is dry compression?

Compression in a cylinder cooled by a water jacket.

What is wet compression?

In this method, the cylinder is not jacketed, but a certain amount of liquid anhydrous ammonia is allowed to enter the cylinder with each stroke, the cylinder walls being cooled by its evaporation.

The wet system is harder on packing, as there are few soft packings that will stand the freezing action of the liquid air hydrous ammonia without becoming hard and causing leaky stuffing boxes.

Management of Refrigerating Machine.—Before starting refrigerating machinery, whether newly installed or after any considerable period of disuse, all piping and joints should be tested for leaks. This may be done, no matter what the system be, using the compression pump to compress air into the piping up to whatever pressure may be considered suitable.

The seriousness of the leakage may then be estimated by the rapidity with which the pressure is lost after allowing the pump to stop. The larger leaks may be determined by the noise made by the escaping air. For the smaller ones the joints are sometimes covered with soap suds so that the escaping air may show itself by blowing a cluster of bubbles. After the points which may show leaks have received proper attention, the system should, for a considerable time, hold the pressure without sensible loss. In this connection, however, it must be remembered that the air as it leaves the compressor will be heated by the work of compression, and as it loses this excess heat in the coils there will be a corresponding loss of pressure. After equality of temperature with the outside air has been reached, however, the further loss of pressure should not be appreciable.

What examination should be made of air and of ammonia machines before operation?

With the air machine no further preliminaries are needed beyond the examination necessary to insure the proper mechanical condition of the compressor and steam cylinders. With the

ammonia machine, however, it is necessary next to exhaust the air from the entire system by working the pumps and discharging through valves provided for this purpose.

When the gauges show the highest vacuum which can be maintained, the valves are closed and the system is ready for charging.

The ammonia is usually provided in steel flasks containing a known weight of the liquid.

FIG. 582.—York enclosed type vertical single acting direct connected compressor.

How is a charge of ammonia introduced?

The flask is connected to the charging valve according to the directions which usually accompany them. In the meantime the machine is run at slow speed with the suction and discharge valves open and the condenser ready for operation. The expansion

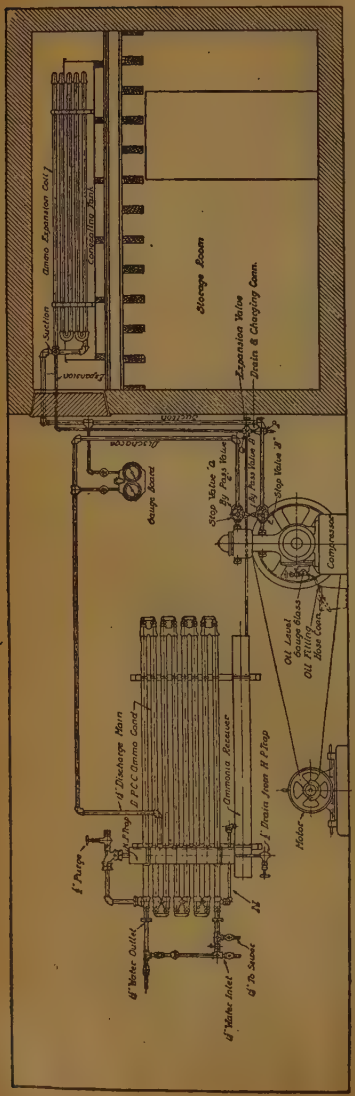


FIG. 533.—Diagram of York small ammonia compressor plant with refrigerator piping.

valve is then closed and the valve of the flask opened, thus allowing the ammonia to be exhausted into the system.

In this manner one flask after another is exhausted into the system until the liquid shows to a suitable height in the glass gauge of the receiver. The charging valve is then closed and the expansion valve opened and regulated until with the machine running at a normal speed the pressure gauges steady down to the pressures usually maintained, and a frosting of all parts of the expansion coils in contact with the air shows that the refrigerating action is in vigorous operation. The weight of ammonia in the flask being known, its complete discharge may be determined by weighing before and after connection with the machine.

What general principles apply in the routine care of refrigerating machinery?

The same principles as for steam engines and pumping machinery.

When air is present in the ammonia system what is its effect?

It decreases the efficiency of the machine.

The principal noticeable symptom of such trouble will probably be a rise in the condenser pressure. Purging valves are usually fitted on the condenser or elsewhere through which such air may be drawn off. To this end it is desirable

to stop the machine for a time to allow the air to collect. It may be then drawn off through a rubber hose or other suitable means and discharged under water. The rise of bubbles will show that air is escaping, while on the other hand the presence of crackling or snapping sounds will indicate that the air is all exhausted and that ammonia is escaping and being absorbed by the water.

Mention a peculiarity of ammonia and air.

Ammonia and air will find smaller leaks than steam.

Special joints are usually required. It must also be remembered that the chemical action between ammonia and copper renders impossible the use of copper, brass or bronze through all parts of the installation with which the ammonia may come in contact.

What sometimes happens in the operation of compressed air refrigerating machinery?

The passages through which the air first passes in its expansion become clogged with a deposit of snow or ice, due to the freezing out of the moisture contained in the air.*

Carbonic Acid System.—This system is used very largely in marine service on passenger and freight steamers, war vessels, etc. It is also used to a considerable extent abroad, partly because carbonic acid is made cheaply as a byproduct in German breweries; in this country it has found favor, principally in hotels and restaurants, because in case of a leak no harm would be done to perishable goods; then, too, the presence of one-half of one per

*NOTE.—In the ***Allen dense air*** machine, where the same air is used over and over again, additional moisture can only come from the small make up air supply, and most of this is removed by the trap provided for this purpose. In operation this trap should be watched in order to make sure that its action is efficient and that there is no danger of the passage of water over into the expansion system. In routine operation it is usually desirable to clean the machine by heating it up and blowing out all the oil and ice deposits. To this end the valves in the main pipes leading the air to and from the coils are closed, thus shutting off the machine from the remainder of the system. A bypass is then opened, connecting the main expansion pipe beyond the oil and snow trap with the main return from the coils. Connections are then opened in the so called hot air pipe leading from the compressor cylinder to the expansion cylinder, and the expansion inlet valve is partly closed. Live steam is then let slowly into the jacket of the oil trap in order to thaw out all ice and hardened oil, and the machine is run moderately for a time, during which the blow off valves of the trap and expansion cylinder are frequently opened until everything appears clean. Then the machine is readjusted to its normal condition and run as before. If it should be suspected that any considerable quantity of oil and water have gotten into the pipe system and are clogging the surfaces, the pipes may be cleaned by running hot air through them and drawing off the oil and water at the bottom of the manifolds of the refrigerating coils.

cent. of ammonia in the atmosphere would be decidedly danger ous, while air containing as high as eight per cent. of carboni acid could be breathed for a short time without any seriou results.

What important advantage has a carbonic acid machine i marine service?

Copper pipes can be used in the condensers.

What is the most marked feature of the carbonic acid system?

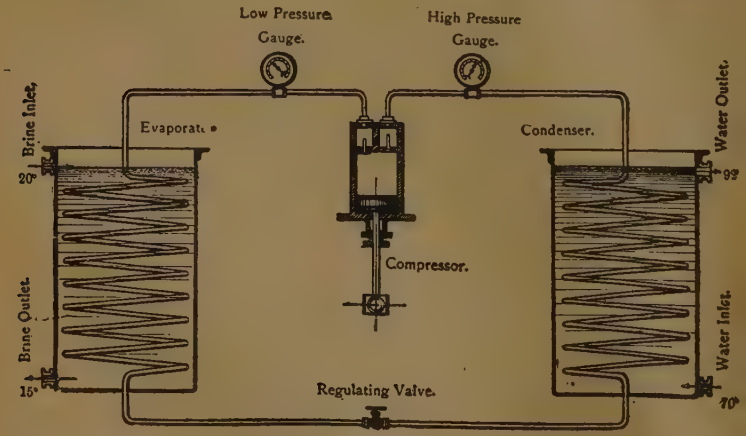


FIG. 584.—Diagrammatic explanation of a carbonic acid refrigerating machine with bri circulation.

The heavy pressure required, varying from 750 pounds temperate climates, with water at 50 degrees Fahr., to 1,20 pounds in the tropics where water is from 80 to 90 degrees Fah

To what degree are carbonic acid machines tested?

Those subject to high pressure are tested to 3,000 poun hydraulic pressure, and again in warm water, by air, to 1,3 pounds.

On what does the safety of a machine depend?

The safety of any machine does not depend on the pressu

at which it works, but on its suitability for the pressure, so that a machine properly constructed for working at even 2,000 pounds per square inch is safer than a machine improperly designed working at only 200 pounds pressure per square inch.

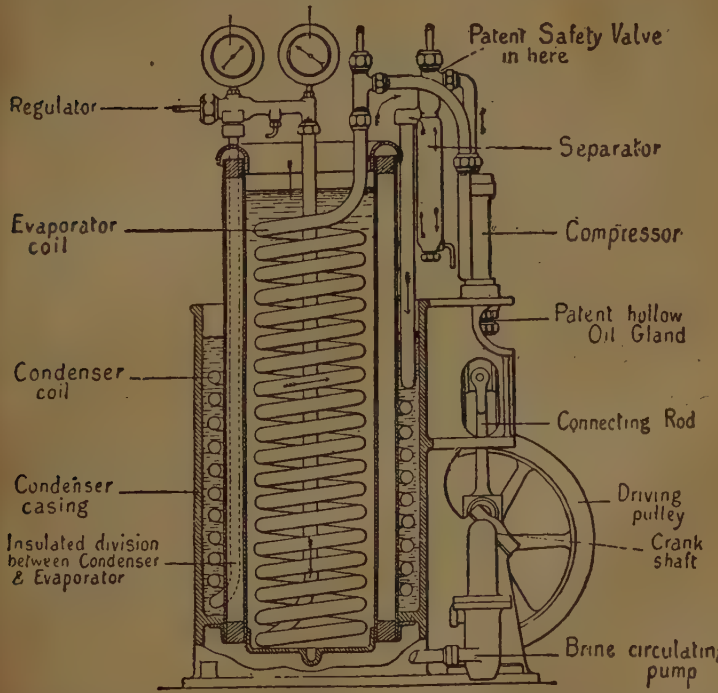


FIG. 585.—Hall marine carbonic acid refrigerating machine. The compressor is directly attached to the body of the condenser which is of the submerged type. The cooler consists of a shell concentric with the condenser, well insulated from same, and containing the evaporating coil. The condenser coil connects with the evaporator coil through the expansion valve shown at the top within easy reach, and each coil is provided with a pressure gauge, the one at the right being the low pressure and at the left the high pressure gauge. The brine is circulated through the cooler by means of a small brine pump attached to the crank shaft.

What is the danger in a leak of carbonic acid?

As it has no odor a leak might not be detected until a workman was so effected by it that he fell to the floor in a faint; as

it is heavier than air, this gas also drops to the lower part of the room and the workman might be suffocated if he was alone.

Describe the evaporator.

It consists of extra heavy iron pipe welded into long lengths inside of which the carbonic acid evaporates. The heat required for evaporation is furnished by brine which surrounds the pipes, or by air, according to which method be used.

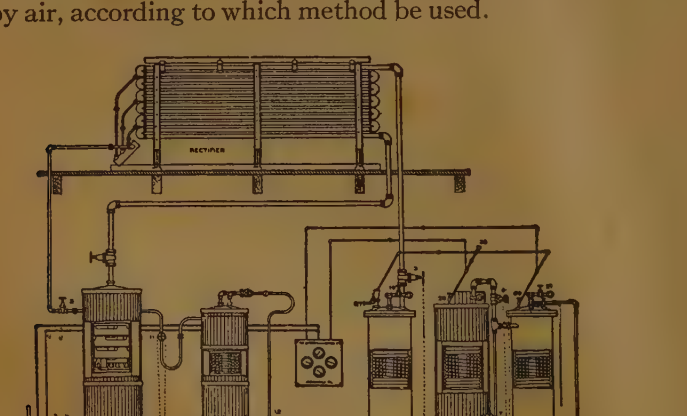


FIG. 586—Carbondale shell type machine.

How is the flow regulated in carbonic acid machines?

By a so called expansion valve between the condenser and evaporator.

What becomes of the glycerine which gets into the compressor?

The gas as it leaves the compressor passes into a separator where the glycerine impinges against the sides of the vessel and adheres to it as it has no affinity for carbonic acid; the glycerine then falls to the bottom of the separator and is drawn off from time to time, while the gas passes on into the condenser.

Is a slight leakage objectionable?

A slight leakage into the compressor would be of advantage as a matter of lubrication, and to seal the clearance space.

How is an excess of glycerine provided for?

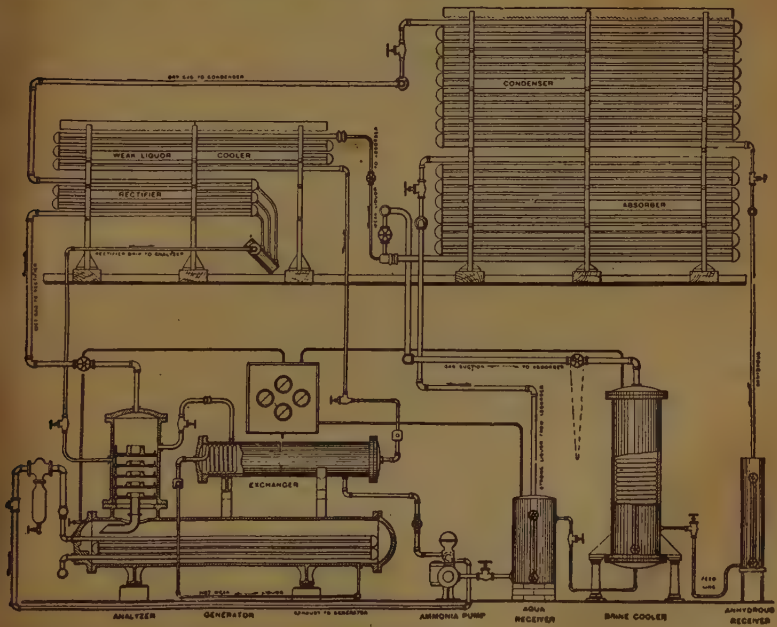


FIG. 587.—Carbondale atmospheric type machine.

Any beyond what is needed to fill the clearance spaces passes through the delivery valves with the gas and drains through a trap to the bottom.

Are there any chemical and mechanical difficulties in the use of glycerine in this way?

No, as carbonic acid and glycerine have no affinity for each other.

How are leaks of glycerine made good?

In large machines by a belt driven pump, and in small on by a hand pump which can be operated every few hours.

Is some leakage of glycerine unavoidable?

Yes, and it must be replaced by a hand pump occasionally.

How is the gland made gas tight?

By means of two cupped leathers on the compressor rod.

When will some refrigerant escape?

When a compressor is opened up for the inspection of valv etc.

Why should liquid carbonic acid be tested?

Because it may contain air, water, oil or grease, carbon sulphide, hydrocarbons, etc.

How is the carbonic acid purified?

Purification is usually effected by passing the gas through series of three sets of horizontal purifying vessels.

In the first purifiers the gas is washed through water, which is slowly continually changed. The next series of purifiers contain sulphuric ac through which the gas percolates, and by which all volatile ethers are remov from the carbonic acid. Finally, the gas is again washed in a very weak so tion of permanganate of potash.

Compressed Air System.—In this system air is compressed t pressure of ten to fifteen atmospheres, and its temperature rais from 75 degrees to 500 or 600 degrees. This heat is conducted by the compressed air being held in a coil surrounded by water, in long pipes passing through the atmosphere as when used rock drilling machinery. The heat may be reduced by cond tion to 75 degrees, but the pressure is still, say, fifteen atm pheres. If this should be allowed to escape into the atmospher temperature of zero to 10 degrees Fahr. would be produced, p of the low temperature being due to the energy required to fo

itself into the air again against an atmospheric pressure of 14.7 pounds per square inch.

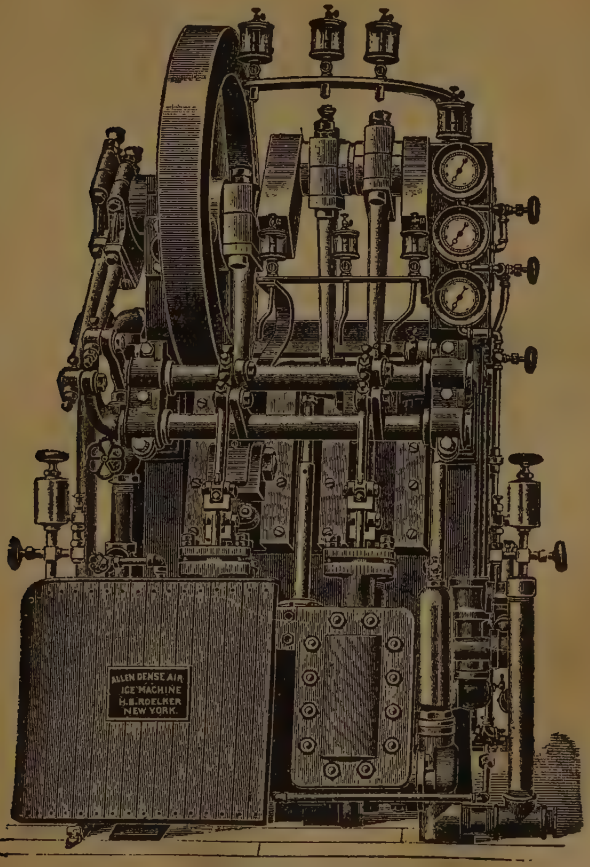


FIG. 588.—Allen marine type dense air machine as shown in diagram in fig. 589.

What is the principle of thermo-dynamics involved in this process?

When a gas is allowed to expand while doing work, the

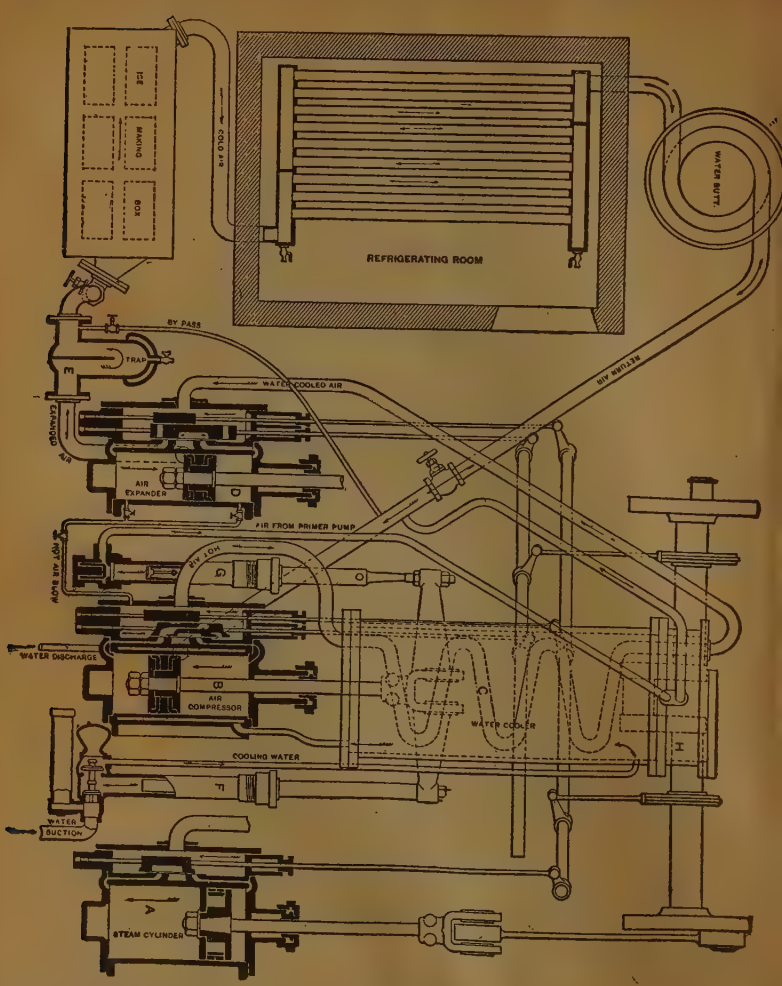


FIG. 589.—Diagrammatic plan view of Allen dense air machine. The following are the important parts: A, The steam cylinder which furnishes the power to its crank shaft, to which the air compressor and the expander are linked. The letters refer to the opposite diagram. B, The air compressor cylinder which compresses the air to about three times the entering pressure. As this causes the air to heat, the cylinder is surrounded by a water jacket to make lubrication practicable. The compression cylinder is constructed with slide valves, instead of the usual conical lift valves, in order to move more quickly and noiselessly. C, a copper coil in a bath of water; the compressed hot air in passing through it cools to the

amount of heat given out by the gas is equal in mechanical energy to the work done.

What are the essential parts of a compressed air plant?

A prime motor, a compressor, a cooling coil of pipe with a water supply, an expander consisting of a cylinder, piston and valves, arranged like those of a steam engine, with cut off.

In operation the cooled compressed air may be admitted during a portion of the stroke, and act expansively during the remainder, thereby compelling it to take up heat from the surrounding atmosphere.

On the return stroke this cooled air is expelled into the coils of the refrigerator, and then returned to the compressor.

What is, therefore, necessary to make use of the refrigerating power of the air?

The expansion cylinder must be well insulated to prevent the expanding air taking up heat from the air surrounding the cylinder. The temperature thus drops, and the air will be able to take up the heat from the refrigerating coils.

What are the main objections to air machines, afloat?

The large space required, the high cost, comparatively, of operation, and the amount of moisture in the air which interfered

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FIG. 589.—*Text continued.*

temperature of the water. The return air cooler which still further reduces the temperature of the air. **D**, The expansion cylinder, to which the cooled compressed air is admitted until it fills one-third of the volume of the cylinder. The air supply is then cut off, and as the piston makes its full stroke to the end of the cylinder the air expands until the tension is about normal, and the expansion cools the air about as much as the compression heated it. It is constructed like a usual steam engine cylinder, with slide valve and cut off valve. It must cut off the pressure at such a point that the expanded air at the end of the stroke of the piston is very nearly of the same pressure as the air contained in the system of pipes. If it were of much higher pressure it would, at exhausting, warm up again, by exerting its remaining power in producing velocities and frictions inside of the apparatus. The air, therefore, leaves this cylinder at a very low temperature and is discharged into a well insulated pipe which conveys it to the point of use; there the pipe is exposed and the cooling is effected, the air returning to be used over. The expander helps the steam cylinder and the air compressor takes the power. **E**, A trap placed just after the expander which intercepts any oil and snow; the trap is provided with a heating pipe and the contents of the trap should be drawn off every few hours. The machine is so arranged that at the same time any frozen deposits in the expander cylinder can be thawed and blown into the trap. **F**, Is the water pump which circulates water around the copper coil **C**, and through a water jacket which surrounds the working cylinder of the air compressor **B**, in order to prevent the heat injuring the packings. **G**, Is a small air compressing pump which takes air from the atmosphere and pushes it into the machine and pipe system. This charges the system with the requisite air pressure when the machine starts to work, and maintains the pressure against leakages occurring at the stuffing boxes and joints. This air, of course, contains the usual atmospheric moisture, and to expel this, the outlet pipe from this pump passes the air through the trap **H**.

not only with the working of the machinery but also in the form of ice or snow is deposited over goods, otherwise the harmlessness of the refrigerant is greatly in its favor.

Describe the working of a Windhausen machine.

In the Windhausen machine, which was for a time largely used in marine service, the air, after being compressed in a

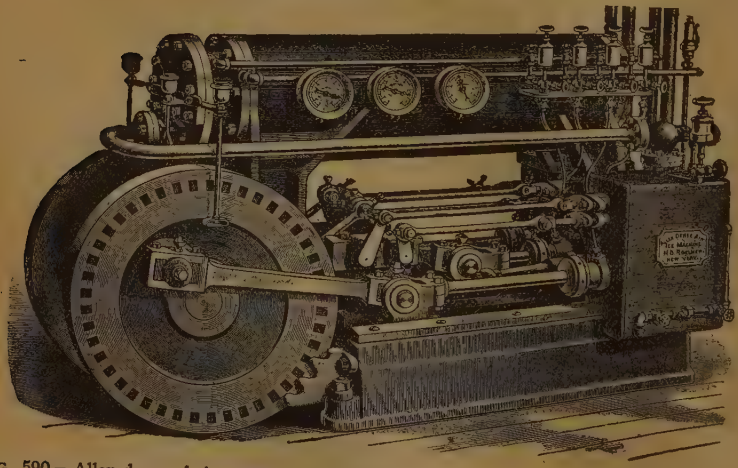

FIG. 590.—Allen dense air ice machine; horizontal type.

cylinder has the heat of compression carried off by cooling water. It then expands in a cylinder, its temperature being reduced corresponding to the amount of work done; it then escapes into the room to be cooled, cooling and ventilating the room at the same time.

What is the temperature in the conveying pipes?

About 60 degrees below zero.

Abstract from,——

UNITED STATES

REGULATIONS

RELATING TO THE

EXAMINATION OF ENGINEERS

FOR

LICENSES AS CHIEF, FIRST, SECOND AND THIRD ENGINEERS

PRESCRIBED BY THE

BOARD OF SUPERVISING INSPECTORS

As Amended January, 1916, and Approved by the Secretary of Commerce

FORM OF APPLICATION FOR LICENSE AS ENGINEER.

....., 190..

To the U. S. Inspectors of Steamboats:

I,....., [if native] being over 21 years of age, having been born at....., State of..... in the year 18 ; ....., [if foreign born] born at ..... in..... ....., in the year 18 was naturalized in the..... Court at..... in the State of....., on the..... day of ....., 1 , and am now a resident of..... in the State of..... hereby respectfully apply for *License* as ....., and submit the following statement of my experience, and testimonials of character and qualifications:

.....

.....

.....

And I further say that I have not made application to the Inspectors of any other District and been rejected within twelve months of the date of this application.

Sworn to before me this.....
day of....., 190..

.....
(City or town).....
State of.....

.....*Inspector.*

The undersigned are well acquainted with..... his habits of life, and qualifications, and know that he is trustworthy and reliable, of sober and industrious habits, and has to our personal knowledge had ample opportunity to and has acquired the necessary knowledge of the theory of steam as a motive power for propelling vessels, as well as the requisite skill in the use, handling, and management of steam engines, such as are used on steamers on the Western and Southern rivers, and that this knowledge has been acquired by practice in boating, and is such as to warrant his being licensed as.....Engineer of Steamers and this statement we do hereby certify on honor.

.....

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Original Licenses

1.—Before an original license is issued to any person to act as a master, mate, pilot, or engineer he shall personally appear before some local board or a supervising inspector for examination. Any person who has attained the age of 19 years and has had the necessary experience shall be eligible for examination: *Provided*, That no person shall receive a license as master or chief engineer before reaching the age of 21 years.

Inspectors shall, before granting an original license to any person to act as an officer of a vessel, require the applicant to make written application upon the blank form furnished by the Department of Commerce, to be filed in the inspectors' office. When practicable applicants for master's, mate's, pilot's, or engineer's license shall present to the inspectors, to be filed with their application, discharges or letters from the master or other officer under whom they have served, certifying to the name of the vessel and in what capacity the applicant has served under him; also period of such service. Inspectors shall also, when practicable, require applicant for pilot's license to have the written indorsement of the master and engineer of the vessel upon which he has served, and of one licensed pilot, as to his qualifications. In the case of applicants for original engineer's license, they shall also, when practicable, have the indorsement of the master and engineer of a vessel on which they have served, together with one other licensed engineer.

The first license issued to any person by a United States inspector shall be considered an original license, where the United States records show no previous issue to such applicant.

No original license shall be issued to any naturalized citizen on less experience in any grade than would have been required of a citizen of the United States by birth. (Sec. 4405, R. S.)

Visual Examinations Required for Original and Renewed Licenses

2.—No original license as master, mate, or pilot of any vessel propelled in whole or in part by steam, gas, fluid, naphtha, alco-vapor, electric, or other like motors, or master or mate of sail vessels, shall be issued except upon the official certificate of a surgeon of the Public Health Service respecting the vision of the person applying for such original license. The word "original" as contemplated in this section shall mean the first license of any character issued to a master, mate, or pilot, and shall not be held to mean, for instance, that a license issued to a master who was previously licensed as a mate or pilot shall be considered an original master's license.

No license as master, mate, or pilot of any class of vessel specified and enumerated in the foregoing paragraph shall be renewed except upon the official certificate of a surgeon of the Public Health Service that the color sense of the applicant for renewal is normal.

Where an applicant for renewal of license is situated so that it would put him to great inconvenience or expense to appear before a surgeon of the Public Health Service for examination, the certificate of a reputable physician or oculist as to the color sense of the applicant shall be accepted in lieu of the certificate of the surgeon of the Public Health Service.

In case an applicant for original license or renewal of license is pronounced color-blind he may, in the discretion of the inspectors, be limited to act as master, mate, or pilot on a vessel navigating in daylight only.

Any applicant for renewal of license who has been refused such renewal on account of the requirements of section 48, Rule V, as amended in January, 1911, respecting visual acuity and color sense, may apply for renewal of license under the provisions of the foregoing section, and nothing herein contained shall debar an applicant who has lost the sight of one eye from securing a renewal of his license, providing that his color sense is normal. (Secs. 4439, 4440, 4442, R. S.)

Re-examinations

3.—No original master's, mate's, pilot's, or engineer's license shall be issued hereafter or grade increased except upon written examination by a board of local inspectors or a supervising inspector, which written examination shall be placed on file in the office of the inspectors issuing said license: *Provided however*, That upon navigable waters of the United States newly opened to steamboat navigation, and where the only pilots obtainable are illiterate Indians or other natives, the fact that such persons can neither read nor write shall not be considered a bar to such Indians or other natives receiving license as pilot of steam vessels, provided they are otherwise qualified therefor.

Before granting or renewing a license, inspectors, shall satisfy themselves that the applicants can properly hear the bell and whistle signals.

When any person makes application for license it shall be the duty of the local inspectors to give the applicant the required examination as soon as practicable. (Secs. 4405, 4439, 4440, 4441, 4442, R. S.)

Examinations and Refusal of Licenses

4.—Any applicant for license who has been duly examined and refused may come before the same local board for reexamination at any time thereafter, but he shall not be examined by any other local board until one year has expired from the date of the refusal.

If the inspectors shall decline to grant the applicant the license asked for, they shall furnish him a statement, in writing, setting forth the cause of their refusal to grant the same. (Sec. 4405, R. S.)

Preparation of Licenses

5.—All licenses hereafter issued to masters, mates, pilots, and engineers shall be filled out on the face with pen and black ink instead of typewritten. Inspectors are directed, when licenses are completed, to draw a broad pen and

black-ink mark through all unused spaces in the body thereof, so as to prevent as far as possible, illegal interpolation after issue. (Sec. 4405, R. S.)

Certificate of Lost License

6.—In case of loss of license, of any class, from any cause, the inspectors, upon receiving satisfactory evidence of such loss, shall issue a certificate to the owner thereof, which shall have the authority of the lost license for the unexpired term, unless in the meantime the holder thereof shall have the grade of his license raised, after due examination, in which case a license in due form for such grade may be issued. (Sec. 4405, R. S.)

Parting With License

7.—Any license granted to a master, mate, pilot, engineer, or operator shall be immediately revoked if, for any purpose, the holder thereof voluntarily parts with its possession or places it beyond his personal control by pledging or depositing it with another. (Sec. 4405, R. S.)

Renewal of Licenses

8.—Whenever an officer shall apply for a renewal of his license for the same grade, the presentation of the old license, with satisfactory certificate of visual examination, where required, and with oath of office, shall be considered sufficient evidence of his title to renewal, which old license, certificate of visual examination, and oath of office shall be retained by the inspectors upon their official files as the evidence upon which the license was renewed: *Provided*, That it is presented within 12 months after the date of its expiration, unless such title has been forfeited or facts shall have come to the knowledge of the inspectors which would render a renewal improper; nor shall any license be renewed more than 30 days in advance of the date of the expiration thereof, unless there are extraordinary circumstances that shall justify a renewal beforehand, in which case the reasons therefor must appear in detail upon the records of the inspectors renewing the license.

Whenever an officer shall apply for renewal of his license for same grade, after 12 months after the date of its expiration, he shall be required to pass an examination for the same grade of license. The renewed license in either case shall receive the next higher number for number of issue of present grade and for number of issue of all grades.

Whenever a licensed officer makes application for a renewal of his license, he shall appear in person before some board of local inspectors or supervising inspector, except that upon renewal of such license for the same grade, when the distance from any local board or supervising inspector is such as to put the person holding the same to great inconvenience and expense to appear in person, he may, upon taking oath of office before any person authorized to administer oaths, and forwarding the same, together with the license to be renewed and certificate of visual examination where required, to the local board or supervising inspector of the district in which he resides or is employed, have the same renewed by the said inspectors, if no valid reason to the contrary be known to them; and they shall attach such oath to the

stub end of the license, which is to be retained on file in their office: *Provided, however*, That any officer holding a license, and who is engaged in a service which necessitates his continuous absence from the United States, may make application in writing for renewal and transmit the same to the board of local inspectors, with his certificate of citizenship, if naturalized, and a statement of the applicant, verified before a consul or other officer of the United States authorized to administer an oath, setting forth the reasons for not appearing in person; and upon receiving the same the board of local inspectors that originally issued such license shall renew the same and shall notify the applicant of such renewal, and no license as master, mate, or pilot of any class of vessel shall be renewed without furnishing a satisfactory certificate of color blindness. (Secs. 4405, 4438, R. S.)

Extension of Route and Raise of Grade of Licenses

9.—Licensed officers serving under five years' license, entitled by license and service to raise of grade, shall have issued to them new licenses for the grade for which they are qualified, the local inspectors to file in their office the old license when surrendered, with the report of the circumstances of the case after the old license and report of the circumstances of the case shall have been reviewed by the supervising inspector of the district, but the grade of no license shall be raised, except as hereinafter provided, unless the applicant can show one year's actual experience in the capacity for which he has been licensed.

Inspectors shall, before granting an extension of route or raise of grade of license, require the applicant to make his written application upon the blank form of application for extension of route or raise of grade of license furnished by the department. When practicable, applicants for extension of route or raise of grade of license shall present to the inspectors, to be filed with the application discharges or letters from the master or other officer under whom they have served, or other satisfactory documentary evidence, certifying to the name of the vessel and in what capacity the applicant has served; also period of such service.

If any board of local inspectors be satisfied that a pilot is entitled by experience and knowledge to unlimited tonnage they may remove any tonnage restrictions which may have been placed upon his license by any other board of local inspectors.

Practical service in the deck department of an ocean or coastwise vessel propelled by machinery shall be accepted when offered in documentary evidence by any person applying for an original license or raise of grade as equal to the same amount of service in any ocean or coastwise steam passenger vessel.

Service on United States motor-propelled light vessels or lighthouse tenders shall be considered as equivalent experience for raise of grade as that obtained on vessels subject to inspection by this Service. (Sec. 4405, R. S.)

Examination of Canceled Licenses by Supervising Inspector

10.—With the exception of operators' licenses, every canceled license renewed, with or without raise of grade, and every canceled license for which a license of a higher grade is issued before the expiration of the five years' term of license shall be submitted to the supervising inspector of the district

for his review, to determine whether both licenses have been issued in accordance with the rules and regulations and whether they are in proper form. The supervising inspector shall personally, carefully examine every canceled license submitted to him. The canceled license shall be promptly examined by the supervising inspector and returned to the local inspectors. (Sec. 4405, R. S.)

CLASSIFICATION OF ENGINEERS

Chief

Chief engineer of ocean steamers.
Chief engineer of condensing lake, bay, and sound steamers.
Chief engineer of non-condensing lake, bay, and sound steamers.
Chief engineer of condensing river steamers.
Chief engineer of non-condensing river steamers.

First Assistant

First assistant engineer of ocean steamers.
First assistant engineer of condensing lake, bay, and sound steamers.
First assistant engineer of non-condensing lake, bay, and sound steamers.
First assistant engineer of condensing river steamers.
First assistant engineer of non-condensing river steamers.

Second Assistant

Second assistant engineer of ocean steamers.
Second assistant engineer of condensing lake, bay, and sound steamers.
Second assistant engineer of non-condensing lake, bay, and sound steamers.
Second assistant engineer of condensing river steamers.

Third Assistant

Third assistant engineer of ocean steamers.
Third assistant engineer of condensing lake and sound steamers.

1. CHIEF

34.—Chief engineers of ocean steamers.

Any person holding chief engineer's license shall be permitted to act as first assistant on any steamer of double the tonnage of same class named in said chief's license

Engineers of all classifications may be allowed to pursue their profession upon all waters of the United States in the class for which they are licensed.

2. FIRST ASSISTANT

First assistant engineer of ocean steamers.

Engineers of lake, bay, and sound steamers who have actually performed the duties of engineer for a period of three years shall be entitled to examination for engineer of ocean steamers, applicant to be examined in the use of

salt water, method employed in regulating the density of the water in boilers, the application of the hydrometer in determining the density of sea water, and the principle of constructing the instrument; and shall be granted such grade as the inspectors having jurisdiction on the Great Lakes and seaboard may find him competent to fill.

Any first assistant engineer of steamers of 1,500 gross tons and over, having had actual service in that position for one year, may, if the local inspectors, in their judgment, deem it advisable, be licensed as chief engineer of lake, bay, sound, or river steamers of 750 gross tons or under, in which case license shall be issued on chief engineers' form of license, which shall be indorsed with authority to act as first assistant engineer of steamers of any tonnage for which he is qualified.

Any person holding a license as first assistant engineer, and having had experience as first assistant engineer for a portion of the year required for raise of grade, may substitute experience as second assistant engineer, while holding first assistant engineer's license, which experience as second assistant engineer shall only count as one-half: *Provided*, That any person having had a first assistant engineer's license for two years, and having had two years' experience as second assistant engineer, shall be eligible for examination for chief engineer's license.

3. SECOND ASSISTANT

Second assistant engineer of ocean steamers.

Any person holding a license as second assistant engineer, and having had experience as second assistant engineer for a portion of the year required for raise of grade, may substitute experience as third assistant engineer, while holding second assistant engineer's license, which experience as third assistant engineer shall only count as one-half: *Provided*, That any person having had a second assistant engineer's license for two years, and having had two years' experience as third assistant engineer, shall be eligible for examination for first assistant engineer's license.

4. THIRD ASSISTANT

Third assistant engineer of ocean steamers.

First, second, and third assistant engineers may act as such on any steamer of the grade of which they hold license, or as such assistant engineer on any steamer of a lower grade than those to which they hold a license.

Any person holding a license as third assistant engineer and having had 12 months' experience as junior engineer, or 12 months' combined service as third assistant engineer and junior engineer, or two years' experience as oiler or water tender, or two years' combined service as oiler and water tender, since receiving said license, shall be eligible for examination for license as second assistant engineer.

Inspectors may designate upon the certificate of any chief or assistant engineer the tonnage of the vessel on which he may act. (Sec. 4441, R. S.)

Qualifications Required for License as Engineer of Steam Vessels, and License Forms Required

35.—No person shall receive an original license as engineer or assistant engineer of steam vessels (except for license as engineer of sawmill boats and pile drivers propelled by steam, and except for special license as engineer of a steam vessel of any kind of 10 gross tons or under on which a licensed engineer is required) who has not served at least 36 months in the engineers' department of a steam vessel, a portion of which experience shall have been obtained within the three years next preceding the application: *Provided*, That any person who has served three years as apprentice to the machinist trade in a marine, stationary, or locomotive engine works, and any person who has served for a period of not less than three years as a locomotive or stationary engineer, and any person graduated as a mechanical engineer from a duly recognized school of technology may be licensed to serve as an engineer of steam vessels after having had not less than one year's experience in the engine department of steam vessels, a portion of which experience shall have been obtained within the three years preceding his application, which fact shall be verified by the certificate, in writing, of the licensed engineer or master under whom the applicant has served, said certificate to be filed with the application of the candidate; and no person shall receive license as above, except for special license, who is not able to determine the weight necessary to be placed on the lever of a safety valve (the diameter of valve, length of lever, distance from center of valve to fulcrum, weight of lever, and weight of valve and stem being known) to withstand any given pressure of steam in a boiler, or who is not able to figure and determine the strain brought on the braces of a boiler with a given pressure of steam, the position and distance apart of braces being known, such knowledge to be determined by an examination in writing, and the report of examination filed with the application in the office of the local inspectors, and no engineer or assistant engineer now holding a license shall have the grade of the same raised without possessing the above qualifications. No original license shall be granted any engineer or assistant engineer who can not read and write and does not understand the plain rules of arithmetic.

No person holding a special engineer's license (Form 878) shall be eligible for examination for a higher grade of license until such person has actually served two full seasons under the authority of his license and one additional full season in a subordinate capacity upon steamers requiring regularly licensed officers.

All licenses to engineers of steam vessels of 10 gross tons and under shall be issued on Form 878, special license to engineers of steam vessels of 10 gross tons and under, and all other licenses to engineers of steam vessels shall be issued on Forms 876, chief engineer's license, and 877, assistant engineer's license, according to grades of chief and assistant engineers specified in Rule V. (Secs. 4405, 4426, 4441, R. S.)

Examination of Boilers and Machinery by Engineer

36.—It shall be the duty of an engineer when he assumes charge of the boilers and machinery of a steamer to forthwith thoroughly examine the same,

and if he finds any part thereof in bad condition, caused by neglect or inattention on the part of his predecessor, he shall immediately report the facts to the master, owner, or agent, and to the local inspectors of the district, who shall thereupon investigate the matter, and if the former engineer has been culpably derelict of his duty they shall suspend or revoke his license. (Sec. 4441, R. S.)

Reports of Accidents, Repairs, and Unsafe Boilers and Machinery by Engineers

37.—Before making general repairs to a boiler of a steam vessel the engineer in charge of such steamer shall report, in writing, the nature of such repairs to the local inspector of the district wherein such repairs are to be made.

And it shall be the duty of all engineers when an accident occurs to the boilers or machinery in their charge tending to render the further use of such boilers or machinery unsafe until repairs are made, or when, by reason of ordinary wear, such boilers or machinery have become so unsafe, to report the same to the local inspectors immediately upon the arrival of the vessel at the first port reached subsequent to the accident or after the discovery of such unsafe condition by said engineer. (Sec. 4441, R. S.)

Engineers of Motor Vessels

38.—No person shall receive an original license as engineer of vessels of above 15 gross tons, propelled by gas, fluid, naphtha, or electric motors, carrying freight or passengers for hire, who has not served at least one year on motor boats or in the engineers' department of steam vessels, or who has not had at least two years' experience in the construction of marine motor engines and their installation. All examinations for license as engineer of motor vessels shall be reduced to writing and filed with the application of the candidate.

Any person holding a license as engineer of steam vessels desiring to act as engineer of motor vessels must appear before a board of local inspectors for examination as to his knowledge of the machinery of such motor vessels, and if found qualified shall be licensed as engineer of motor vessels. (Sec. 4426, R. S.)

PART TWELVE

STEAM AND THE STEAM TABLES
INDEX

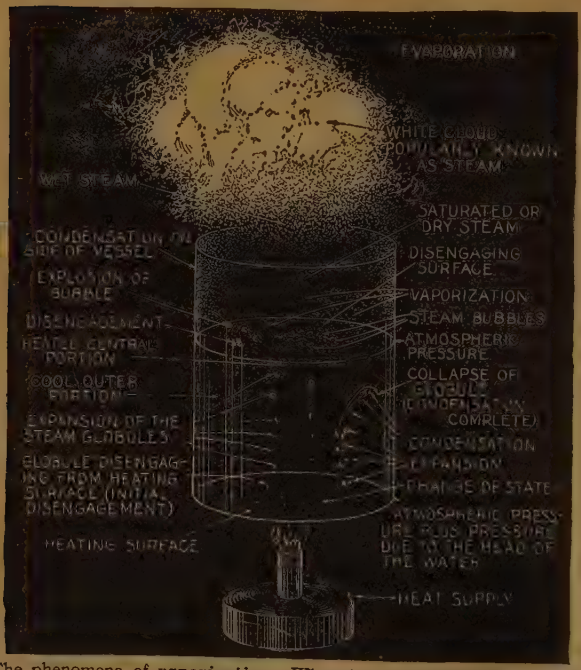


FIG. 591.—The phenomena of ***vaporization***. When heat is applied to water in a vessel as shown, it is conducted through the heating surface to the lower state which gradually becomes heated to the boiling point. This is followed by the formation of globules of steam on the heating surface indicating that particles of the water have received a supply of heat equal to the sensible and latent heat of steam at the pressure existing at the bottom of the vessel, thus a *change of state* has taken place, and this may be called *initial vaporization* as distinguished from vaporization or the completion of the process. As more heat is added, more of the water adjacent to the globules is converted into steam which causes the globules to increase in size until their buoyancy becomes sufficient to overcome the tension with the heating surface and *initial disengagement* takes place. Following the course of a globule disengaging from the central and hottest portion of the heating surface, it rapidly rises to the surface, and expands as it rises because the pressure gradually decreases due to diminishing head of water. On reaching the *disengaging surface*, a bubble is formed which at once bursts as the water closes in behind the steam contained in the bubble, thus completing the process of vaporization of the original particles of water; that is to say, a *change of state* has taken place and the steam has been disengaged from the water.

NOTE.—It should be noted in the above illustration that all of the steam globules formed on the heating surface do not reach the surface, as for instance, the globule A, found near the side of the vessel will, as it rises, take same course as A1, A2, A3, expanding as it rises. After passing the portion A3, it may be deflected over toward the side of the vessel into relatively cold water as indicated by the arrow, giving up its heat to the cold water, resulting in *condensation* and the gradual collapse of the globule as indicated. It should be noted further that the pressure at the bottom of the vessel or heating surface being greater than the pressure at the disengaging surface, the temperature at which initial vaporization takes place is greater than that of vaporization proper.

Steam is a colorless, expansive, invisible fluid. The white cloud seen issuing from an exhaust pipe, and usually called steam, is not steam but in reality a fog of minute liquid particles produced by condensation.

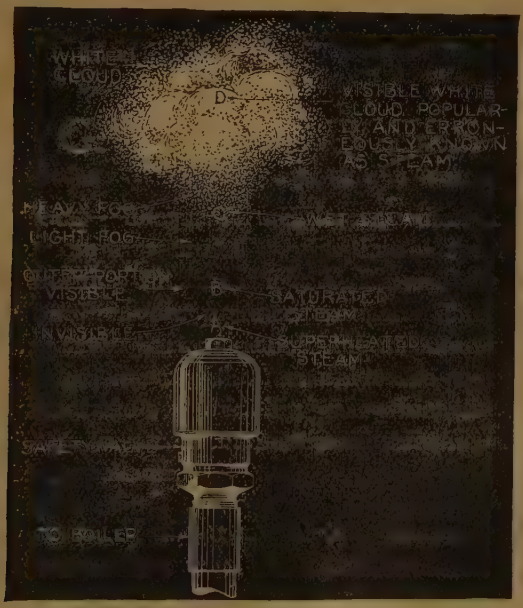


FIG. 592.—The various ***states of steam*** as exemplified in the operation of a safety valve. By closely observing a safety when blowing off, as for instance the safety valve on a locomotive, or better the safety valve on a marine boiler, furnishing superheated steam, very interesting phenomena can be observed. At A, very close, the escaping gas is invisible being at this point *superheated*. At B, the outline of the ascending column is seen, the interior being invisible and gradually becoming "foggy" and as the vapor ascends from B, to D, denoting the gradual reduction in temperature, the steam becoming saturated and wet, reaching the white state at D, where it is ***popularly*** and ***erroneously*** known as "steam." ***Steam*** *is invisible*. The reason the so called wet steam can be seen is because wet steam is ***a mechanical mixture*** *made up of saturated steam which is invisible, and which holds in suspension a multiplicity of fine water globules formed by* **condensation;** it is the collection of these water globules or condensate that is visible.

How is steam classified according to its quality?

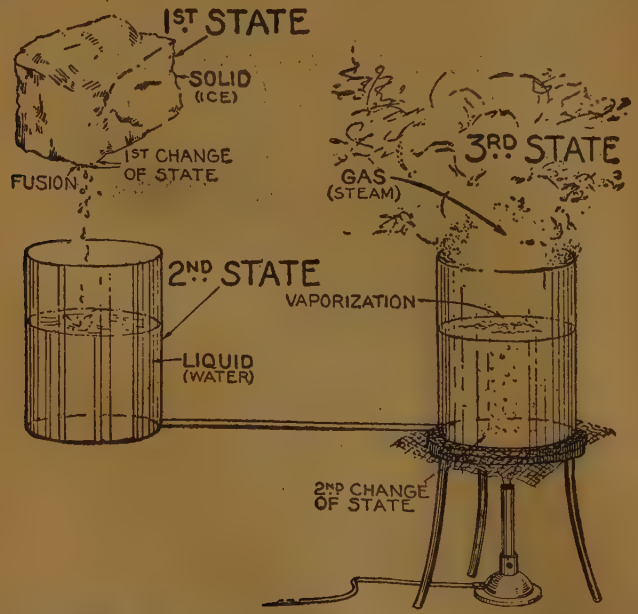
As wet, dry, saturated, superheated or gaseous.

Wet steam contains intermingled moisture, mist or spray, and has the same temperature as dry saturated steam of the same pressure.

Dry steam contains no moisture; it may be either saturated or superheated.

Saturated steam is steam of a temperature due to its pressure.

**Superheated steam* is steam having a temperature *above* that due to its pressure.



FIGS. 593 to 595.—The three states: Solid, liquid and gas. The cake of ice represents a substance in the solid state. If the temperature of the surrounding air be above the freezing point (32° Fahr.) *the ice will gradually melt*, that is to say, **change its state** *from solid to liquid* this process being known as **fusion.** If sufficient heat be transferred to the liquid, *it will boil*, that is to say, **change its state** *from liquid to gas*, this process being known as **vaporization.** Very interesting phenomena takes place during these changes, which are explained in the accompanying text.

Ques. Under what conditions does steam exist?

Ans. When there is the proper relation between the

*NOTE.—A term sometimes, though ill advisedly, used for highly superheated steam is gaseous steam or steam gas. The saving in the water consumption of a steam engine due to superheating the steam is a little over one per cent for each ten degrees of superheat.

temperature of the water and the external pressure. For instance, for a given temperature of the water there is a certain external pressure above which steam will not form.

Ques. How is steam produced?

Ans. By heating water until it reaches the *boiling point.*

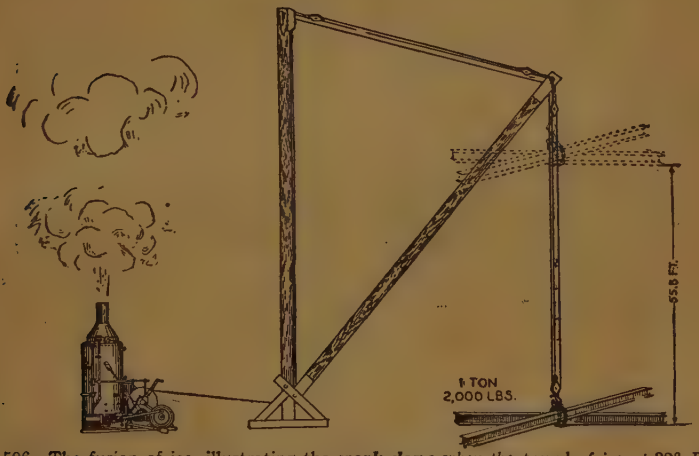
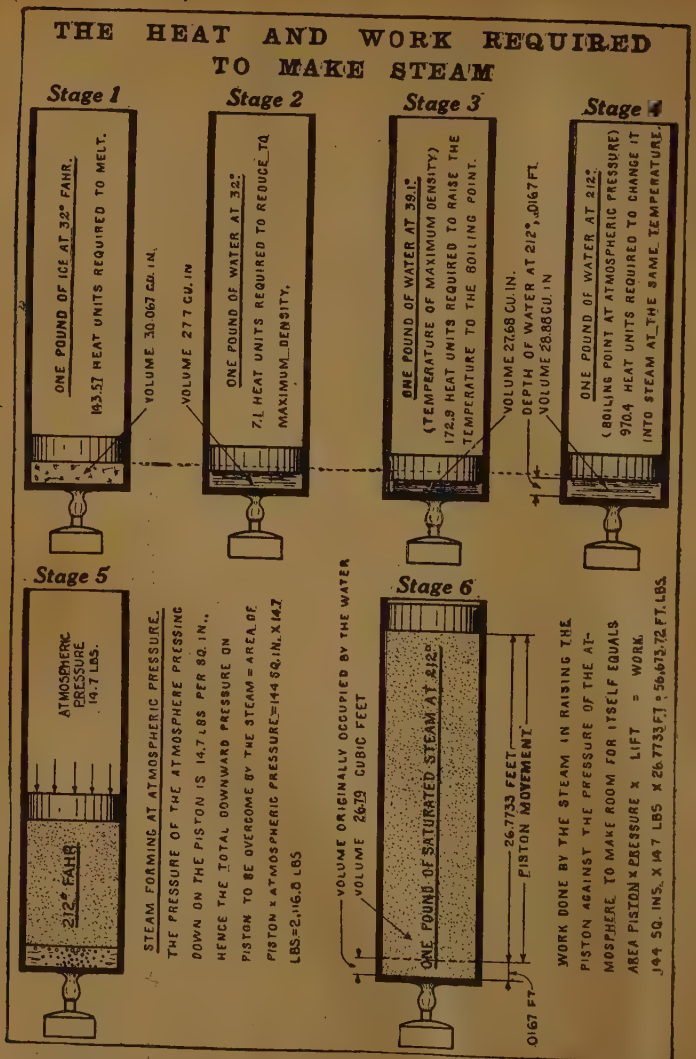


FIG. 596—The fusion of ice, illustrating the ***work done*** *when the pound of ice at 32° Fahr. is melted or converted into water at the same temperature.* The latent heat of fusion being 143.57 heat units, and since one heat unit is equivalent to 778 ft. lbs. the work done during the fusion of one pound of ice is $778 \times 143.57 = 111{,}698$ ft. lbs. This is approximately equivalent to the work done when a hoisting engine hoists 2,000 lbs. a distance of 55.8 ft. as shown in the illustration.

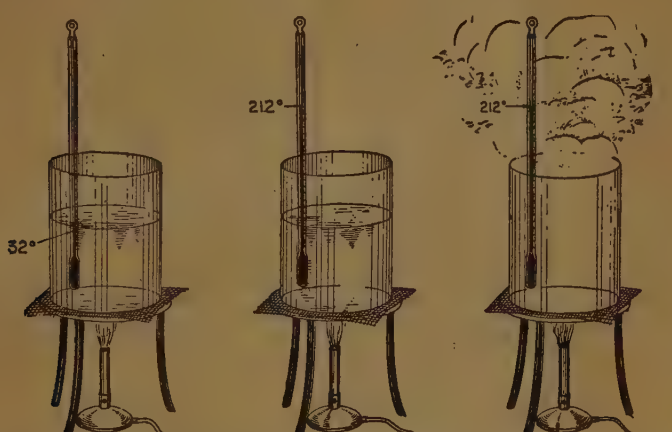
What an Engineer should know about Steam.—As has been stated, the *medium* which transmits heat energy to the engine to be transformed into mechanical work is a very remarkable substance; it disobeys the general law of expansion by heating, and, can exist in three different states, that is, as

1. A solid (ice);
2. A liquid (water), or
3. A gas (steam),


THE HEAT AND WORK REQUIRED TO MAKE STEAM
Stage 1
ONE POUND OF ICE AT 32° FAHR.
143.57 HEAT UNITS REQUIRED TO MELT.
VOLUME 30.067 CU. IN.
Stage 2
ONE POUND OF WATER AT 32°
7.1 HEAT UNITS REQUIRED TO REDUCE TO MAXIMUM DENSITY.
VOLUME 27.7 CU. IN
Stage 3
ONE POUND OF WATER AT 39.1°
(TEMPERATURE OF MAXIMUM DENSITY)
172.9 HEAT UNITS REQUIRED TO RAISE THE TEMPERATURE TO THE BOILING POINT.
VOLUME 27.68 CU. IN.
DEPTH OF WATER AT 212°=.0167 FT.
VOLUME 28.86 CU. IN
Stage 4
ONE POUND OF WATER AT 212°
(BOILING POINT AT ATMOSPHERIC PRESSURE)
970.4 HEAT UNITS REQUIRED TO CHANGE IT INTO STEAM AT THE SAME TEMPERATURE.
Stage 5
ATMOSPHERIC PRESSURE 14.7 LBS.
212° FAHR.
STEAM FORMING AT ATMOSPHERIC PRESSURE.
THE PRESSURE OF THE ATMOSPHERE PRESSING DOWN ON THE PISTON IS 14.7 LBS PER SQ. IN., HENCE THE TOTAL DOWNWARD PRESSURE ON PISTON TO BE OVERCOME BY THE STEAM = AREA OF PISTON x ATMOSPHERIC PRESSURE=144 SQ.IN. X 14.7 LBS.=2,116.8 LBS
Stage 6
VOLUME ORIGINALLY OCCUPIED BY THE WATER
VOLUME 26.79 CUBIC FEET
ONE POUND OF SATURATED STEAM AT 212°
26.7733 FEET
PISTON MOVEMENT
.0167 FT.
WORK DONE BY THE STEAM IN RAISING THE PISTON AGAINST THE PRESSURE OF THE ATMOSPHERE. TO MAKE ROOM FOR ITSELF EQUALS AREA PISTON x PRESSURE x LIFT = WORK.
144 SQ. INS. X 14.7 LBS X 26.7733 FT. = 56,672.72 FT. LBS.

FIGS. 597 to 602.—*From ice to steam,* illustrating the *six stages* in the making of steam from ice at 32° Fahr.

depending upon conditions of pressure and temperature. These changes are shown in the accompanying series of diagrams (figs. 597 to 602), which represent the several stages in transforming a pound of ice at 32° Fahr. into saturated steam at 212°, the temperature corresponding to atmospheric pressure. The engineer should make a careful study of these diagrams and the matter following to properly understand the nature of the medium he has to deal with in the operation of an engine.



FIGS. 603 to 605.—Experiment illustrating the ***latent heat of steam*** or the considerable amount of heat which must be added to water at the boiling point to convert it into steam at the same temperature. In fig. 603, suppose the glass vessel to contain one pound of water at 32° Fahr., and heat be transferred to it, as indicated by the Bunsen burner, at such rate that its temperature is raised to the boiling point 212° in five minutes. In this time the water has received $212-32=180$ heat units. Now, if the heat supply be continued at the same rate, it will require (since the latent heat of steam at atmospheric pressure is 970.4 heat units) $970.4 \div 180 = 5.39$ times as long, or $5.39 \times 5 = 26.95$ minutes to convert the pound of water at 212° (fig. 604) into steam at the same temperature as indicated by the empty beaker in fig. 605. That is to say, it takes over five times as much heat to convert water at 212° into steam at the same temperature as it does to raise the same amount of water from the freezing point 32° to 212°. This experiment can be easily performed with water at ordinary temperature say 60°. In this case, if it takes five minutes to raise its temperature to 212°, it would require $970.4 \div (212-60) = 6.38$ times as long or $6.38 \times 5 = 31.9$ minutes to evaporate the water at 212°. It is thus seen that the latent heat is the big item in steam making. In the well known ***"naphtha launch"*** and ***"alco-vapor launch"*** naphtha and alcohol were used respectively in the boilers in the place of water because of the excessive latent heat of the latter. This with a given heating surface or weight (an important factor in marine construction) more power could be developed with the above mentioned liquids than with water, because of their relative low latent heat of evaporation. For instance, for alcohol the latent heat is 364.3 heat units or only a little over one-third of that of water. Operators of alco-vapor launches who have tried using water in the boiler can appreciate the considerable difference in the results obtained. From experiments made by the Gas Engine and Power Co., builders of the naphtha launches, it was claimed that the power obtained on the brake was in the ratio of about 5 to 9 for steam and naphtha, that is, the same quantity of heat was turned into nearly twice as much work by the expansion of naphtha vapor as by the expansion of steam under the same conditions. Some of the results obtained during the tests were: ***with steam,*** mean pressure 37.99 lbs., *r.p.m.*, 312.6; ***with naphtha,*** mean pressure 55.8 *r.p.m.*, 552.2.

From Ice to Steam

	British thermal units		Mechanical equivalent in foot pounds		Volume
1. Latent Heat of Fusion					*In cu. ins.*
a To *melt* one lb of ice at 32° Fahr *without* changing its temperature	143.57§				
b *Mechanical equivalent* = 143.57 × 777.52 =			111,628.55		
c *Volume* {of one lb of ice at 32° Fahr.					30.067
" " " water " "					27.7
Values given below are "above 32° Fahr."					
2. Sensible Heat					
a. To raise the temperature of one lb of water from 32° to 212° Fahr. (212°—32°) =		180.*			
b *Mechanical equivalent* = 180 × 777.52 =				139,953.6	
c *Volume* {of one lb of water at 39.1° Fahr., point of maximum density					27.68
" " " 212° " boiling point (atmospheric pressure)					28.88
3. Latent Heat of Evaporation					
Being the heat necessary to convert one lb. of water at 212° Fahr into steam of the same temperature and consisting of:					
a. The internal latent heat					
1 To overcome the molecular attraction, that is, to separate the particles of the water in the formation of steam =	897.51				
2. *Mechanical equivalent* = 897.51 × 777.52 =			697,831.98		
b. The external latent heat					
1. To overcome atmospheric pressure, that is, to push back the atmosphere in order to make room for the steam = mechanical equivalent (item *3 b* 2) ÷ 777.52 =	72.89				*In cu. ft.*
2 *Mechanical equivalent* = 144 sq. ins. × 14.7 lbs. × (26.79 ft. — .0167 ft.)† =			56,673.72		
3 *Volume* {of one lb. of water at 212° Fahr					0167
" " " " steam " " "					26.79
c. Total latent heat					
1 For evaporation at 212° Fahr., the total latent heat, called simply *latent heat* = item *3 a* 1 + item *3 b* 1 =		970.4*			
2. *Mechanical equivalent* = item *3 a* 2 + item *3 b* 2 =				754,505.7	
4. Total Heat					
a. Above 32° Fahr in the *water* = item *2 a*	180				
b. " 32° " " " *steam* = item *2 a* + item *3 c* 1 =		1150.4*			
c. *Mechanical equivalent* {for the *water* = item *2 b* =			139,953.6		
" " *steam* = item *2 b* + item *3 c* 2 =				894,459.3	

§U. S. Bureau of Standards (1915). *According to Marks and Davis. †As calculated by F. D. Graham.
‡Some early steam tables gives values *"above 0° Fahr."*

When the temperature of steam becomes less than that corresponding to its pressure what change occurs?

Condensation; that is, it ceases to exist as steam and becomes water.

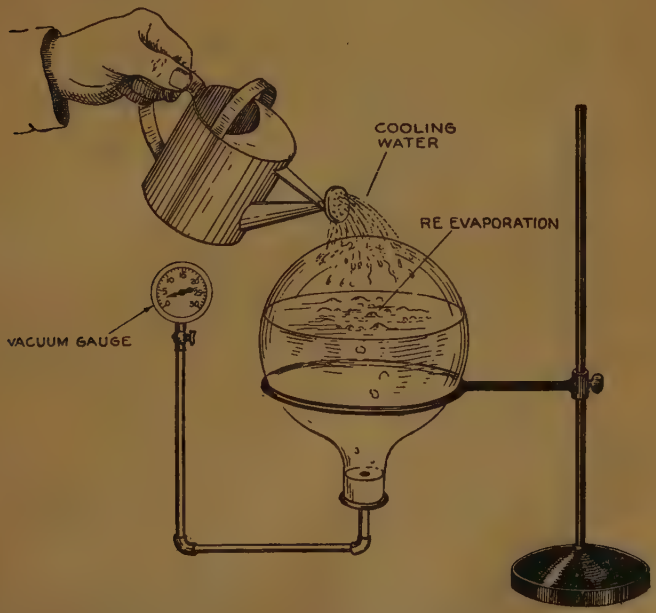


FIG. 606.—***Lowering the boiling point*** by diminishing the pressure. Fill a round bottomed flask with water and boil. After it has boiled some time, until the air has been drawn out of the flask by the steam, insert a rubber stopper, having fitted to it a connection leading to a vacuum gauge and invert the flask as shown. The vacuum gauge will now read zero. Now, if some cold water be poure t over the flask, the temperature will fall rapidly and some of the steam will condense, thus lowering the pressure within the flask, that is, the vacuum gauge will read say 5 or 10 inches indicating a vacuum. *The reduced pressure disturbs the equilibrium between pressure and temperature and the water will boil until equilibrium is again restored.* The operation may be repeated several times without reheating, the pressure gradually falling each time. At the city of Quito, Ecuador, water boils at 194° Fahr., and on the top of Mt. Blanc at 183°. Again, in a steam boiler in which the pressure is 200 lbs., the boiling point is 387.7°.

Can the pressure in a closed flask (as in fig. 606) containing steam and water be reduced to zero by reducing the temperature of the water?

It could, if the mass could be cooled to 459.6° below zero Fahr.,* but at ordinary temperatures the pressure could not be reduced to zero. Water contains a small amount of air which it gives up when evaporated; this of itself would prevent the pressure falling to zero, if all the steam were condensed. If the

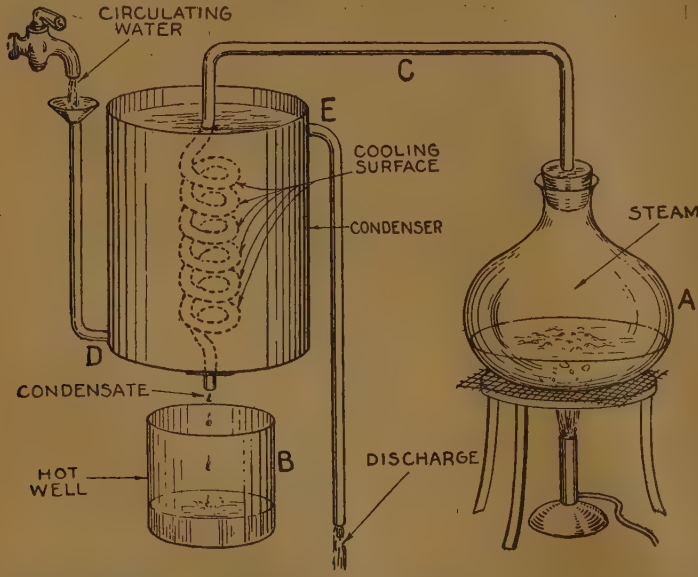


FIG. 607.—The ***condensation of steam.*** If water be boiled in a flask A, and the steam thus produced be led off through pipe C, having a coiled section surrounded by cold water, it will here be cooled below the boiling point and will therefore condense, the condensate passing out into the receptacle B, as water. The cooling or "circulating" water enters the condenser at the lowest point D, and leaving at the highest point E.

contents of the flask be cooled to 80° there would be inside the flask a pressure of one-half pound per square inch, if the water be cooled to 32°, the pressure would be .089 pounds. There is then always some pressure inside the flask, the intensity of which depends upon the temperature of the water.

*NOTE.—459.6° below zero Fahr., is a point called the absolute zero. A perfect gas contracts in volume a definite amount for each degree in temperature it is cooled. The ***absolute zero*** then is *the point to which a perfect gas must be cooled to reduce its volume to nothing.*

How to Use the Steam Table.—The various properties of saturated steam are usually presented in tabulated form for convenience in making calculations. The values of the properties of steam here given are condensed from Marks and Davis' steam tables which are now (1917) generally accepted as the standard, and are the most accurate that have yet been published.

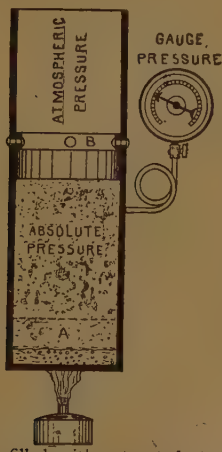


FIG. 608.—***The generation of steam*** at pressures above the atmosphere. If a ring B, be riveted in a cylinder to limit the movement of a piston resting, at the beginning of the experiment, on top of a small quantity of water (as indicated by dotted lines A, and heat be applied, the piston (assumed to have no weight) will rise as steam is formed at atmospheric pressure until it comes in contact with the ring B. Additional heat will cause the pressure of the steam to increase in a definite rate corresponding to the temperature until all the water is evaporated, the cylinder being now filled with saturated steam. The pressure of this saturated steam will depend on the relation between its volume and the volume of the water from which it was generated. If more heat be now added, the temperature of the steam will increase above that due to its pressure, and the steam becomes superheated. Removing the heat supply, the temperature of the gas will gradually diminish, and it loses its superheat and returns to the saturated condition, at which point condensation begins, the pressure and temperature during these changes gradually falling. Condensation continuing until all the steam has condensed, the piston returning to its initial position A. If, during the cooling process, the piston be fastened at the ring B, the pressure of the steam will become less than the atmospheric pressure outside when the temperature falls below 212° Fahr., forming a so called vacuum. The degree of vacuum now increases, or in other words, the pressure under the cylinder or absolute pressure becomes less and less until, when all the steam is condensed, it becomes approximately zero, or 14.72 lbs. lower than the pressure of the atmosphere or gauge pressure (assuming the barometer reads 30 inches). The pressure remains a little above zero because of the small percentage of air originally contained in the water, which does not recombine with it when the steam condenses, that is, a perfect vacuum is not formed because of this air, necessitating, in the case of condensing engines, an air or so called vacuum pump.

In the first column is given the gauge pressure, and in the second, the absolute pressure. The second column, then, is made up by adding 14.7 lbs. to the pressures given in the first column. Before using a steam table, the difference between gauge and absolute pressure should be thoroughly understood.

The third column gives the temperature in degrees Fahrenheit, beginning with the freezing point 32°, which for convenience is taken as *the temperature of no heat.*

Column four gives the total heat above 32° in each pound of water at the different pressures; similarly in column five is given the total heat above 32° for each pound weight of steam.

The latent heat in the next column is clearly the difference between the heat in the steam and the heat in the water, or column 5—column 4.

The relative volume of the steam is given in column seven; for instance, one cubic foot of water at 212° will occupy 26.79 cu. ft. when evaporated into steam at the same temperature.

Column eight gives the weight per cu. ft., and the last two columns the entropy values.

The following examples illustrate how to use the steam table:

Example.—How many heat units are saved in heating 25 lbs. of feed water from 90 to 202°?

In column 4, total heat in the water at 201.96° = 169.9
In column 4, total heat in the water at 90° = 58.0
Heat units saved per lb. of feed water = 111.9
Total heat units saved = 111.9 × 25 = 2,797.5

Example.—What is the weight of 20 cu. ft. of steam at 150 lbs. absolute pressure?

The weight of 1 cu. ft. steam at 150 lbs. abs. is given in column 9 at .332 lb. Twenty cu. ft. then will weigh: .332 × 20 = 6.64 lbs.

Example.—How much more heat is required to generate 26 lbs. of steam at 150 lbs. abs., than at 90 lbs. abs.

In column 5 total heat in steam at 150 lbs. abs. = 1,193.4
In column 5 total heat in steam at 90 lbs. abs. = 1,184.4
Excess heat required per pound (weight) = 9 B. t. u.
Total for 26 lbs. = 9 × 26 = 23.4 B. t. u.

Example.—How much heat is absorbed by the cooling water, if a condensing engine exhaust 17 lbs. of steam per hour at a terminal pressure of 18 lbs. absolute into a 28 inch vacuum.

In column 5, total heat in the steam at 18 lbs. abs. = 1,154.20
In column 4, total heat in the water with 28″ vacuum = 67.97
Heat to be absorbed per lb. of steam . . . . . = 1,086.23
Total heat absorbed by the cooling water per hour

1,086.23 × 17 = 18,465.9 B. t. u.

Properties of Saturated Steam

Condensed from Marks and Davis' Steam Tables and Diagrams, 1909, by permission of the publishers, Longmans, Green & Co.

Vacuum, Inches of Mercury.	Absolute Pressure, Lbs. per Sq. In.	Temperature, Fahrenheit.	Total Heat above 32° F: In the Water h Heat-Units.	Total Heat above 32° F: In the Steam H Heat-Units.	Latent Heat, L = H − h Heat-Units.	Volume, Cu. Ft. in 1 Lb. of Steam.	Weight of 1 Cu. Ft. Steam, Lb.	Entropy of the Water.	Entropy of Evaporation.
29.74	0.0886	32	0.00	1073.4	1073.4	3294	0.000304	0.0000	2.1832
29.67	0.1217	40	8.05	1076.9	1068.9	2438	0.000410	0.0162	2.1394
29.56	0.1780	50	18.08	1081.4	1063.3	1702	0.000587	0.0361	2.0865
29.40	0.2562	60	28.08	1085.9	1057.8	1208	0.000828	0.0555	2.0358
29.18	0.3626	70	38.06	1090.3	1052.3	871	0.001148	0.0745	1.9868
28.89	0.505	80	48.03	1094.8	1046.7	636.8	0.001570	0.0932	1.9398
28.50	0.696	90	58.00	1099.2	1041.2	469.3	0.002131	0.1114	1.8944
28.00	0.946	100	67.97	1103.6	1035.6	350.8	0.002851	0.1295	1.8505
27.88	1	101.83	69.8	1104.4	1034.6	333.0	0.00300	0.1327	1.8427
25.85	2	126.15	94.0	1115.0	1021.0	173.5	0.00576	0.1749	1.7431
23.81	3	141.52	109.4	1121.6	1012.3	118.5	0.00845	0.2008	1.6840
21.78	4	153.01	120.9	1126.5	1005.7	90.5	0.01107	0.2198	1.6416
19.74	5	162.28	130.1	1130.5	1000.3	73.33	0.01364	0.2348	1.6084
17.70	6	170.06	137.9	1133.7	995.8	61.89	0.01616	0.2471	1.5814
15.67	7	176.85	144.7	1136.5	991.8	53.56	0.01867	0.2579	1.5582
13.63	8	182.86	150.8	1139.0	988.2	47.27	0.02115	0.2673	1.5380
11.60	9	188.27	156.2	1141.1	985.0	42.36	0.02361	0.2756	1.5202
9.56	10	193.22	161.1	1143.1	982.0	38.38	0.02606	0.2832	1.5042
7.52	11	197.75	165.7	1144.9	979.2	35.10	0.02849	0 2902	1.4895
5.49	12	201.96	169.9	1146.5	976.6	32.36	0.03090	0.2967	1.4760
3.45	13	205.87	173.8	1148.0	974.2	30.03	0.03330	0.3025	1.4639
1.42	14	209.55	177.5	1149.4	971.9	28.02	0.03569	0.3081	1.4523
lbs. gauge	14.70	212	180.0	1150.4	970.4	26.79	0.03732	0.3118	1.4447
0.3	15	213.0	181.0	1150.7	969.7	26.27	0.03806	0.3133	1.4416
1.3	16	216.3	184.4	1152.0	967.6	24.79	0.04042	0.3183	1.4311
2.3	17	219.4	187.5	1153.1	965.6	23.38	0.04277	0.3229	1.4215
3.3	18	222.4	190.5	1154.2	963.7	22.16	0.04512	0.3273	1.4127
4.3	19	225.2	193.4	1155.2	961.8	21.07	0.04746	0.3315	1.4045
5.3	20	228.0	196.1	1156.2	960.0	20.08	0.04980	0.3355	1.3965
6.3	21	230.6	198.8	1157.1	958.3	19.18	0.05213	0.3393	1.3887
7.3	22	233.1	201.3	1158.0	956.7	18.37	0.05445	0.3430	1.3811
8.3	23	235.5	203.8	1158.8	955.1	17.62	0.05676	0.3465	1.3739
9.3	24	237.8	206.1	1159.6	953.5	16.93	0.05907	0.3499	1.3670
10.3	25	240.1	208.4	1160.4	952.0	16.30	0.0614	0.3532	1.3604
11.3	26	242.2	210.6	1161.2	950.6	15.72	0.0636	0.3564	1.3542
12.3	27	244.4	212.7	1161.9	949.2	15.18	0.0659	0.3594	1.3483

Properties of Saturated Steam—*Continued*

Gauge Pressure, Lbs. per Sq. In.	Absolute Pressure, Lbs. per sq. in.	Temperature, Fahrenheit.	Total Heat above 32° F		Latent Heat, L = H − h Heat-Units.	Volume, Cu. Ft. in 1 Lb. of Steam.	Weight of 1 Cu. Ft. Steam, Lb.	Entropy of the Water.	Entropy of Evaporation.
			In the water H Heat-Units.	In the Steam H Heat-Units.					
13.3	28	246.4	214.8	1162.6	947.8	14.67	0.0682	0.3623	1.3425
14.3	29	248.4	216.8	1163.2	946.4	14.19	0.0705	0.3652	1.3367
15.3	30	250.3	218.8	1163.9	945.1	13.74	0.0728	0.3680	1.3311
16.3	31	252.2	220.7	1164.5	943.8	13.32	0.0751	0.3707	1.3257
17.3	32	254.1	222.6	1165.1	942.5	12.93	0.0773	0.3733	1.3205
18.3	33	255.8	224.4	1165.7	941.3	12.57	0.0795	0.3759	1.3155
19.3	34	257.6	226.2	1166.3	940.1	12.22	0.0818	0.3784	1.3107
20.3	35	259.3	227.9	1166.8	938.9	11.89	0.0841	0.3808	1.3060
21.3	36	261.0	229.6	1167.3	937.7	11.58	0.0863	0.3832	1.3014
22.3	37	262.6	231.3	1167.8	936.6	11.29	0.0886	0.3855	1.2969
23.3	38	264.2	232.9	1168.4	935.5	11.01	0.0908	0.3877	1.2925
24.3	39	265.8	234.5	1168.9	934.4	10.74	0.0931	0.3899	1.2882
25.3	40	267.3	236.1	1169.4	933.3	10.49	0.0953	0.3920	1.2841
26.3	41	268.7	237.6	1169.8	932.2	10.25	0.0976	0.3941	1.2800
27.3	42	270.2	239.1	1170.3	931 2	10.02	0.0998	0.3962	1.2759
28.3	43	271.7	240.5	1170.7	930.2	9.80	0.1020	0.3982	1.2720
29.3	44	273.1	242.0	1171.2	929.2	9.59	0.1043	0.4002	1.2681
30.3	45	274.5	243.4	1171.6	928.2	9.39	0.1065	0.4021	1.2644
31.3	46	275.8	244.8	1172.0	927.2	9.20	0.1087	0.4040	1.2607
32.3	47	277.2	246.1	1172.4	926.3	9.02	0.1109	0.4059	1.2571
33.3	48	278.5	247.5	1172.8	925.3	8.84	0.1131	0.4077	1.2536
34.3	49	279.8	248.8	1173.2	924.4	8.67	0.1153	0.4095	1.2502
35.3	50	281.0	250.1	1173.6	923.5	8.51	0.1175	0.4113	1.2468
36.3	51	282.3	251.4	1174.0	922.6	8.35	0.1197	0.4130	1.2435
37.3	52	283.5	252.6	1174.3	921.7	8.20	0.1219	0.4147	1.2402
38.3	53	284.7	253.9	1174.7	920.8	8.05	0.1241	0.4164	1.2370
39.3	54	285.9	255.1	1175.0	919.9	7.91	0.1263	0.4180	1.2339
40.3	55	287.1	256.3	1175.4	919.0	7.78	0.1285	0.4196	1.2309
41.3	56	288.2	257.5	1175.7	918.2	7.65	0.1307	0.4212	1.2278
42.3	57	289.4	258.7	1176.0	917.4	7.52	0.1329	0.4227	1.2248
43.3	58	290.5	259.8	1176.4	916.5	7.40	0.1350	0.4242	1.2218
44.3	59	291.6	261.0	1176.7	915.7	7.28	0.1372	0.4257	1.2189
45.3	60	292.7	262.1	1177.0	914.9	7.17	0.1394	0.4272	1.2160
46.3	61	293.8	263.2	1177.3	914.1	7.06	0.1416	0.4287	1.2132
47.3	62	294.9	264.3	1177.6	913.3	6.95	0.1438	0.4302	1.2104
48.3	63	295.9	265.4	1177.9	912.5	6.85	0.1460	0.4316	1.2077
49.3	64	297.0	266.4	1178.2	911.8	6.75	0.1482	0.4330	1.2050
50.3	65	298.0	267.5	1178.5	911.0	6.65	0.1503	0.4344	1.2024
51.3	66	299.0	268.5	1178.8	910.2	6.56	0.1525	0.4358	1.1998
52.3	67	300.0	269.6	1179.0	909.5	6.47	0.1547	0.4371	1.1972

Properties of Saturated Steam—*Continued*

Gauge Pressure, Lbs. per Sq. In.	Absolute Pressure, Lbs per sq. in.	Temperature, Fahrenheit	Total Heat above 32° F		Latent Heat, L = H − h Heat-Units.	Volume, Cu. Ft. in 1 Lb. of Steam.	Weight of 1 Cu. Ft. Steam, Lb.	Entropy of the Water.	Entropy of Evaporation.
			In the water h Heat-Units.	In the Steam H Heat-Units.					
53.3	68	301.0	270.6	1179.3	908.7	6.38	0.1569	0.4385	1.1946
54.3	69	302.0	271.6	1179.6	908.0	6.29	0.1590	0.4398	1.1921
55.3	70	302.9	272.6	1179.8	907.2	6.20	0.1612	0.4411	1.1896
56.3	71	303.9	273.6	1180 1	906.5	6.12	0.1634	0.4424	1.1872
57.3	72	304.8	274.5	1180.4	905.8	6.04	0.1656	0.4437	1.1848
58.3	73	305.8	275.5	1180.6	905.1	5.96	0.1678	0.4449	1.1825
59.3	74	306.7	276.5	1180.9	904.4	5.89	0.1699	0.4462	1.1801
60.3	75	307.6	277.4	1181.1	903.7	5.81	0 1721	0.4474	1.1778
61.3	76	308.5	278.3	1181.4	903.0	5.74	0.1743	0.4487	1.1755
62.3	77	309.4	279.3	1181.6	902.3	5.67	0.1764	0.4499	1.1732
63.3	78	310.3	280.2	1181.8	901.7	5.60	0.1786	0.4511	1.1710
64.3	79	311.2	281.1	1182.1	901.0	5.54	0.1808	0.4523	1.1687
65.3	80	312.0	282.0	1182.3	900.3	5.47	0.1829	0.4535	1.1665
66.3	81	312.9	282.9	1182.5	899.7	5.41	0.1851	0 4546	1.1644
67.3	82	313.8	283.8	1182.8	899.0	5.34	0.1873	0.4557	1.1623
68.3	83	314.6	284.6	1183.0	898.4	5.28	0.1894	0.4568	1.1602
69.3	84	315.4	285.5	1183.2	897.7	5.22	0.1915	0.4579	1.1581
70.3	85	316.3	286.3	1183.4	897.1	5.16	0.1937	0.4590	1.1561
71.3	86	317.1	287.2	1183.6	896.4	5.10	0.1959	0 4601	1.1540
72.3	87	317.9	288.0	1183.8	895.8	5.05	0.1980	0.4612	1.1520
73.3	88	318.7	288.9	1184.0	895.2	5.00	0.2001	0.4623	1.1500
74.3	89	319.5	289.7	1184.2	894.6	4.94	0.2023	0 4633	1.1481
75.3	90	320.3	290.5	1184.4	893.9	4.89	0 2044	0.4644	1.1461
76.3	91	321.1	291.3	1184.6	893.3	4.84	0.2065	0.4654	1.1442
77.3	92	321.8	292.1	1184.8	892.7	4.79	0.2087	0.4664	1.1423
78.3	93	322.6	292.9	1185.0	892.1	4 74	0.2109	0.4674	1.1404
79.3	94	323.4	293.7	1185.2	891.5	4.69	0.2130	0.4684	1.1385
80.3	95	324.1	294.5	1185.4	890.9	4.65	0.2151	0.4694	1.1367
81.3	96	324.9	295.3	1185.6	890.3	4.60	0.2172	0.4704	1.1348
82.3	97	325.6	296.1	1185.8	889.7	4.56	0.2193	0.4714	1.1330
83.3	98	326.4	296.8	1186.0	889.2	4.51	0.2215	0.4724	1.1312
84.3	99	327.1	297.6	1186.2	888.6	4.47	0.2237	0.4733	1.1295
85.3	100	327.8	298.3	1186.3	888.0	4.429	0.2258	0.4743	1.1277
87.3	102	329.3	299.8	1186.7	886.9	4.347	0.2300	0.4762	1.1242
89.3	104	330.7	301.3	1187.0	885.8	4.268	0.2343	0.4780	1.1208
91.3	106	332.0	302.7	1187.4	884.7	4.192	0.2336	0.4798	1.1174
93.3	108	333.4	304.1	1187.7	883.6	4.118	0.2429	0.4816	1.1141
95.3	110	334.8	305.5	1188.0	882.5	4.047	0.2472	0.4834	1.1108
97.3	112	336.1	306.9	1188.4	881.4	3.978	0.2514	0.4852	1.1076
99.3	114	337.4	308.3	1188.7	880.4	3.912	0.2556	0.4869	1.1045

Properties of Saturated Steam—*Continued*

Gauge Pressure, Lbs. per Sq. In.	Absolute Pressure, Lbs. per Sq. In.	Temperature, Fahrenheit.	Total Heat above 32° F		Latent Heat, L = H − h Heat-Units.	Volume, Cu. Ft. in 1 Lb. of Steam.	Weight of 1 Cu. Ft. Steam, Lb.	Entropy of the Water.	Entropy of Evaporation.
			In the Water h Heat-Units.	In the Steam H Heat-Units.					
101.3	116	338.7	309.6	1189.0	879.3	3.848	0.2599	0.4880	1.1014
103.3	118	340.0	311.0	1189.3	878.3	3.786	0.2641	0.4903	1.0984
105.3	120	341.3	312.3	1189.6	877.2	3.726	0.2683	0.4919	1.0954
107.3	122	342.5	313.6	1189.8	876.2	3.668	0.2726	0.4935	1.0924
109.3	124	343.8	314.9	1190.1	875.2	3.611	0.2769	0.4951	1.0895
111.3	126	345.0	316.2	1190.4	874.2	3.556	0.2812	0.4967	1.0865
113.3	128	346.2	317.4	1190.7	873.3	3.504	0.2854	0.4982	1.0837
115 3	130	347.4	318.6	1191.0	872.3	3.452	0.2897	0.4998	1.0809
117.3	132	348.5	319.9	1191.2	871.3	3.402	0.2939	0.5013	1.0782
119.3	134	349.7	321.1	1191.3	870.4	3.354	0.2981	0.5028	1.0755
121.3	136	350.8	322.3	1191.7	869.4	3.308	0.3023	0.5043	1.0728
123.3	138	352.0	323.4	1192.6	868.5	3.263	0.3065	0.5057	1.0702
125.3	140	353.1	324.6	1192.2	867.6	3.219	0.3107	0.5072	1.0675
127.3	142	354.2	325.8	1192.5	866.7	3.175	0.3150	0.5086	1.0649
129.3	144	355.3	326.9	1192.7	865.8	3.133	0.3192	0.5100	1.0624
131.3	146	356.3	328.0	1192.9	864.9	3.092	0.3234	0.5114	1.0599
133.3	148	357.4	329.1	1193.2	864.0	3.052	0.3276	0.5128	1.0574
135.3	150	358.5	330.2	1193.4	863.2	3.012	0.3320	0.5142	1.0550
137.3	152	359.5	331.4	1193.6	862.3	2.974	0.3362	0.5155	1.0525
139.3	154	360.5	332.4	1193.8	861.4	2.938	0.3404	0.5169	1.0501
141.3	156	361.6	333.5	1194.1	860.6	2.902	0.3446	0.5182	1.0477
143.3	158	362.6	334.6	1194.3	859.7	2.868	0.3488	0.5195	1.0454
145.3	160	363.6	335.6	1194.5	858.8	2.834	0.3529	0.5208	1.0431
147.3	162	364.6	336.7	1194.7	858.0	2.801	0.3570	0.5220	1.0409
149.3	164	365.6	337.7	1194.9	857.2	2.769	0.3612	0.5233	1.0387
151.3	166	366.5	338.7	1195.1	856.4	2.737	0.3654	0.5245	1.0365
153.3	168	367.5	339.7	1195.3	855.5	2.706	0.3696	0.5257	1.0343
155.3	170	368.5	340.7	1195.4	854.7	2.675	0.3738	0.5269	1.0321
157.3	172	369.4	341.7	1195.6	853.9	2.645	0.3780	0.5281	1.0300
159.3	174	370.4	342.7	1195.8	853.1	2.616	0.3822	0.5293	1.0278
161.3	176	371.3	343.7	1196.0	852.3	2.588	0.3864	0.5305	1.0257
163.3	178	372.2	344.7	1196.2	851.5	2.560	0.3906	0.5317	1.0235
165.3	180	373.1	345.6	1196.4	850.8	2.533	0.3948	0.5328	1.0215
167.3	182	374.0	346.6	1196.6	850.0	2.507	0.3989	0.5339	1.0195
169.3	184	374.9	347.6	1196.8	849.2	2.481	0.4031	0.5351	1.0174
171.3	186	375.8	348.5	1196.9	848.4	2.455	0.4073	0.5362	1.0154
173.3	188	376.7	349.4	1197.1	847.7	2.430	0.4115	0.5373	1.0134
175.3	190	377.6	350.4	1197.3	846.9	2.406	0.4157	0.5384	1.0114
177.3	192	378.5	351.3	1197.4	846.1	2.381	0.4199	0.5395	1.0095
179.3	194	379.3	352.2	1197.6	845.4	2.358	0.4241	0.5405	1.0076

Properties of Saturated Steam—*Continued*

Gauge Pressure, Lbs. per Sq. In.	Absolute Pressure, Lbs. per Sq. In.	Temperature, Fahrenheit.	Total Heat above 32° F: In the Water h Heat-Units.	Total Heat above 32° F: In the Steam H Heat-Units.	Latent Heat, $L = H - h$ Heat-Units.	Volume, Cu. Ft. in 1 Lb. of Steam.	Weight of 1 Cu. Ft. Steam, Lb.	Entropy of the Water.	Entropy of Evaporation.
181.3	196	380.2	353.1	1197.8	844.7	2.335	0.4283	0.5416	1.0056
183.3	198	381.0	354.0	1197.9	843.9	2.312	0.4325	0.5426	1.0038
185.3	200	381.9	354.9	1198.1	843.2	2.290	0.437	0.5437	1.0019
190.3	205	384.0	357.1	1198.5	841.4	2.237	0.447	0.5463	0.9973
195.3	210	386.0	359.2	1198.8	839.6	2.187	0.457	0.5488	0.9928
200.3	215	388.0	361.4	1199.2	837.9	2.138	0.468	0.5513	0.9885
205.3	220	389.9	363.4	1199.6	836.2	2.091	0.478	0.5538	0.9841
210.3	225	391.9	365.5	1199.9	834.4	2.046	0.489	0.5562	0.9799
215.3	230	393.8	367.5	1200.2	832.8	2.004	0.499	0.5586	0.9758
220.3	235	395.6	369.4	1200.6	831.1	1.964	0.509	0.5610	0.9717
225.3	240	397.4	371.4	1200.9	829.5	1.924	0.520	0.5633	0.9676
230.3	245	399.3	373.3	1201.2	827.9	1.887	0.530	0.5655	0.9638
235.3	250	401.1	375.2	1201.5	826.3	1.850	0.541	0.5676	0.9600
245.3	260	404.5	378.9	1202.1	823.1	1.782	0.561	0.5719	0.9525
255.3	270	407.9	382.5	1202.6	820.1	1.718	0.582	0.5760	0.9454
265.3	280	411.2	386.0	1203.1	817.1	1.658	0.603	0.5800	0.9385
275.3	290	414.4	389.4	1203.6	814.2	1.602	0.624	0.5840	0.9316
285.3	300	417.5	392.7	1204.1	811.3	1.551	0.645	0.5878	0.9251
295.3	310	420.5	395.9	1204.5	808.5	1.502	0.666	0.5915	0.9187
305.3	320	423.4	399.1	1204.9	805.8	1.456	0.687	9.5951	0.9125
315.3	330	426.3	402.2	1205.3	803.1	1.413	0.708	0.5986	0.9065
325.3	340	429.1	405.3	1205.7	800.4	1.372	0.729	0.6020	0.9006
335.3	350	431.9	408.2	1206.1	797.8	1.334	0.750	0.6053	0.8949
345.3	360	434.6	411.2	1206.4	795.3	1.298	0.770	0.6085	0.8894
355.3	370	437.2	414.0	1206.8	792.8	1.264	0.791	0.6116	0.8840
365.3	380	439.8	416.8	1207.1	790.3	1.231	0.812	0.6147	0.8788
375.3	390	442.3	419.5	1207.4	787.9	1.200	0.833	0.6178	0.8737
385.3	400	444.8	422	1208	786	1.17	0.86	0.621	0.868
435.3	450	456.5	435	1209	774	1.04	0.96	0.635	0.844
485.3	500	467.3	448	1210	762	0.93	1.08	0.648	0.822
535.3	550	477.3	459	1210	751	0.83	1.20	0.659	0.801
585.3	600	486.6	469	1210	741	0.76	1.32	0.670	0.783
Source	684	500	484	1209	725	0.66	1.52	0.686	0.755
	1062	550	542	1200	658	0.42	2.36	0.743	0.650
	1574	600	604	1176	572	0.27	3.75	0.799	0.540
	2265	650			441	0.16	6.2		0.396
	2974	689				0.05			
*	3075	700							
*	4300.2	752							
†	5017.1	779							
†	5659.9	810.6							

*From G. A. Goodenough's tables 1915.

†Calculated by J. McFarlane Gray—*Proc. Inst. M.E.*, July, 1889.

Properties of Superheated Steam

(Condensed from Marks and Davis' Steam Tables and Diagrams.)

v = specific volume in cu. ft. per lb., h = total heat, from water at 32° F. in B.t.u. per lb., n = entropy, from water at 32°.

Press. Abs. Lbs. per Sq. In.	Temp. Sat. Steam.	Degrees of Superheat.									
		0	50	100	150	200	250	300	400	500	600
20	228.0	v 20.08	21.69	23.25	24.80	26.33	27.85	29.37	32.39	35.40	38.40
		h 1156.2	1179.9	1203.5	1227.1	1250.6	1274.1	1297.6	1344.8	1392.2	1440.0
		n 1.7320	1.7652	1.7961	1.8251	1.8524	1.8781	1.9026	1.9479	1.9893	2.0275
40	267.3	v 10.49	11.33	12.13	12.93	13.70	14.48	15.25	16.78	18.30	19.80
		h 1169.4	1194.0	1218.4	1242.4	1266.4	1290.3	1314.1	1361.6	1409.3	1457.4
		n 1.6761	1.7089	1.7392	1.7674	1.7940	1.8189	1.8427	1.8867	1.9271	1.9646
60	292.7	v 7.17	7.75	8.30	8.84	9.36	9.89	10.41	11.43	12.45	13.46
		h 1177.0	1202.6	1227.6	1252.1	1276.4	1300.4	1324.3	1372.2	1420.0	1468.2
		n 1.6432	1.6761	1.7062	1.7342	1.7603	1.7849	1.8081	1.8511	1.8908	1.9279
80	312.0	v 5.47	5.92	6.34	6.75	7.17	7.56	7.95	8.72	9.49	10.24
		h 1182.3	1208.8	1234.3	1259.0	1283.6	1307.8	1331.9	1379.8	1427.9	1476.2
		n 1.6200	1.6532	1.6833	1.7110	1.7368	1.7612	1.7840	1.8265	1.8658	1.9025
100	327.8	v 4.43	4.79	5.14	5.47	5.80	6.12	6.44	7.07	7.69	8.31
		h 1186.3	1213.8	1239.7	1264.7	1289.4	1313.6	1337.8	1385.9	1434.1	1482.5
		n 1.6020	1.6358	1.6658	1.6933	1.7188	1.7428	1.7656	1.8079	1.8468	188.29
120	341.3	v 3.73	4.04	4.33	4.62	4.89	5.17	5.44	5.96	6.48	6.99
		h 1189.6	1217.9	1244.1	1269.3	1294.1	1318.4	1342.7	1391.0	1439.4	1487.8
		n 1.5873	1.6216	1.6517	1.6789	1.7041	1.7280	1.7505	1.7924	1.8311	1.8669
140	353.1	v 3.22	3.49	3.75	4.00	4.24	4.48	4.71	5.16	5.61	6.06
		h 1192.2	1221.4	1248.0	1273.3	1298.2	1322.6	1346.9	1395.4	1443.8	1492.4
		n 1.5747	1.6096	1.6395	1.6666	1.6916	1.7152	1.7376	1.7792	1.8177	1.8533
160	363.6	v 2.83	3.07	3.30	3.53	3.74	3.95	4.15	4.56	4.95	5.34
		h 1194.5	1224.5	1251.3	1276.8	1301.7	1326.2	1350.6	1399.3	1447.9	1496.6
		n 1.5639	1.5993	1.6292	1.6561	1.6810	1.7043	1.7266	1.7680	1.8063	1.8418
180	373.1	v 2.53	2.75	2.96	3.16	3.35	3.54	3.72	4.09	4.44	4.78
		h 1196.4	1227.2	1254.3	1279.9	1304.8	1329.5	1353.9	1402.7	1451.4	1500.3
		n 1.5543	1.5904	1.6201	1.6468	1.6716	1.6948	1.7169	1.7581	1.7962	1.8316
200	381.9	v 2.29	2.49	2.68	2.86	3.04	3.21	3.38	3.71	4.03	4.34
		h 1198.1	1229.8	1257.1	1282.6	1307.7	1332.4	1357.0	1405.9	1454.7	1503.7
		n 1.5456	1.5823	1.6120	1.6385	1.6632	1.6862	1.7082	1.7493	1.7872	1.8225
220	389.9	v 2.09	2.28	2.45	2.62	2.78	2.94	3.10	3.40	3.69	3.98
		h 1199.6	1232.2	1259.6	1285.2	1310.3	1335.1	1359.8	1408.8	1457.7	1506.8
		n 1.5379	1.5753	1.6049	1.6312	1.6558	1.6787	1.7005	1.7415	1.7792	1.8145
240	397.4	v 1.92	2.09	2.26	2.42	2.57	2.71	2.85	3.13	3.40	3.67
		h 1200.9	1234.3	1261.9	1287 6	1312.8	1337.6	1362.3	1411.5	1460.5	1509.8
		n 1.5309	1.5690	1.5985	1.6246	1.6492	1.6720	1.6937	1.7344	1.7721	1.8072
260	404.5	v 1.78	1.94	2.10	2.24	2.39	2.52	2.65	2.91	3.16	3.41
		h 1202.1	1236.4	1264.1	1289.9	1315.1	1340.0	1364.7	1414.0	1463.2	1512.5
		n 1.5244	1.5631	1.5926	1.6186	1.6430	1.6658	1.6874	1.7280	1.7655	1.8005

Properties of Superheated Steam—*Continued*

Press. Abs. Lbs. per Sq. In.	Temp. Sat. Steam.	Degrees of Superheat.									
		0	50	100	150	200	250	300	400	500	600
280	411.2	v 1.66	1.81	1.95	2.09	2.22	2.35	2.48	2.72	2.95	3.19
		h 1203.1	1238.4	1266.2	1291.9	1317.2	1342.2	1367.0	1416.4	1465.7	1515.1
		n 1.5185	1.5580	1.5873	1.6133	1.6375	1.6603	1.6818	1.7223	1.7597	1.7945
300	417.5	v 1.55	1.69	1.83	1.96	2.09	2.21	2.33	2.55	2.77	2.99
		h 1204.1	1240.3	1268.2	1294.0	1319.3	1344.3	1369.2	1418.6	1468.0	1517.6
		n 1.5129	1.5530	1.5824	1.6082	1.6323	1.6550	1.6765	1.7168	1.7541	1.7889
350	431.9	v 1.33	1.46	1.58	1.70	1.81	1.92	2.02	2.22	2.41	2.60
		h 1206.1	1244.6	1272.7	1298.7	1324.1	1349.3	1374.3	1424.0	1473.7	1523.5
		n 1.5002	1.5423	1.5715	1.5971	1.6210	1.6436	1.6650	1.7052	1.7422	1.7767
400	444.8	v 1.17	1.28	1.40	1.50	1.60	1.70	1.79	1.97	2.14	2.30
		h 1207.7	1248.6	1276.9	1303.0	1328.6	1353.9	1379.1	1429.0	1478.9	1528.9
		n 1.4894	1.5336	1.5625	1.5880	1.6117	1.6342	1.6554	1.6955	1.7323	1.7666
450	456.5	v 1.04	1.14	1.25	1.35	1.44	1.53	1.61	1.77	1.93	2.07
		h 1209	1252	1281	1307	1333	1358	1383	1434	1484	1534.0
		n 1.479	1.526	1.554	1.580	1.603	1.626	1.647	1.687	1.723	1.758
500	467.3	v 0.93	1.03	1.13	1.22	1.31	1.39	1.47	1.62	1.76	1.89
		h 1210	1256	1285	1311	1337	1362	1388	1438	1489	1539
		n 1.470	1.519	1.548	1.573	1.597	1.619	1.640	1.679	1.715	1.750

Volume of Superheated Steam—Linde's equation (1905),

$$pv = 0.5962T - p(1 + 0.0014p)\frac{(150{,}300{,}000}{T^3} - 0.0833)$$

in which p, is in lb. per sq. in., v, is in cu. ft. and T, is the absolute temperature on the Fahrenheit scale, has been used in the computation of Marks & Davis' steam tables.

Specific heat of superheated steam.—Mean specific heats from the temperature of saturation to various temperatures at several pressures—*Knoblauch and Jakob* (from Peabody's Tables).

Lb. per sq. in.		14.2	28.4	56.9	85.3	113.3	142.2	170.6	199.1	227.5	256.0	284.4
Temp. sat. °F.		210	248	289	316	336	350	368	381	392	403	412
°F.	°C.											
212	100	0.463										
302	150	.462	0.478	0.515								
392	200	.462	.475	.502	0.530	0.560	0.597	0.635	0.677			
482	250	.463	.474	.495	.514	.532	.552	.570	.588	0.609	0.635	0.664
572	300	.464	.475	.492	.505	.517	.530	.541	.550	.561	.572	.585
662	350	.468	.477	.492	.503	.512	.522	.529	.536	.543	.550	.557
752	400	.473	.481	.494	.504	.512	.520	.526	.531	.537	.542	.547

The Rationalization of Regnault's Experiments on Steam.—(J. McFarlane Gray, *Proc. Inst. M. E.*, July, 1889.)—The formulæ constructed by Regnault are strictly empirical, and were based entirely on his experiments. They are therefore not valid beyond the range of temperatures and pressures observed.

Mr. Gray has made a most elaborate calculation, based not on experiments but on fundamental principles of thermodynamics, from which he deduces formulæ for the pressure and total heat of steam, and presents tables calculated therefrom which show substantial agreement with Regnault's figures. He gives the following examples of steam-pressures calculated for temperatures beyond the range of Regnault's experiments:

Temperature		Pounds per	Temperature		Pounds per
C.	Fahr.	Sq. In.	C.	Fahr.	Sq. In.
230	446	406.9	340	644	2156.2
240	464	488.9	360	680	2742.5
250	482	579.9	380	716	3448.1
260	500	691.6	400	752	4300.2
280	536	940.0	415	779	5017.1
300	572	1261.8	427	800.6	5659.9
320	608	1661.9			

These pressures are higher than those obtained by Regnault's formula, which gives for 415° C. only 4067.1 lbs. per square inch.

Available Energy in Expanding Steam.—Rankine Cycle. (J. B. Stanwood, *Power*, June 9, 1908.)—A simple formula for finding, with the aid of the steam and entropy tables, the available energy per pound of steam in *B.t.u.* when it is expanded adiabatically from a higher to a lower pressure is:

$$U = H - H_1 + T\,(N_1 - N).$$

U = available *B.t.u.* in 1 lb. of expanding steam; H and H_1 total heat in 1 lb. steam at the two pressures; T = absolute temperature at the lower pressure; $N - N_1$, difference of entropy of 1 lb. of steam at the two pressures.

Example.—Required the available *B.t.u.* in 1 lb. steam expanded from 100 lbs. to 14.7 lbs. absolute. $H = 1186.3$; $H_1 = 1150.4$; $T = 672$; $N = 1.602$; $N_1 = 1.756$. $35.9 + 103.5 = 138.4$.

Efficiency of the Cycle.—Let the steam be made from feed water at 212°. Heat required $= 1186.3 - 180 = 1006.3$; efficiency $= 138.4 \div 1006.3 = 0.1375$.

Rankine Cycle.—This efficiency is that of the Rankine cycle, which assumes that the steam is expanded adiabatically to the exhaust pressure and temperature, and that the feed water from which the steam is made is introduced into the system at the temperature of the exhaust.

Carnot Cycle.—The Carnot ideal cycle, which assumes that all the heat entering the system enters at the highest temperature, and in which the efficiency is $(T_1 - T_2) \div T_1$, gives $(327.8 - 212) \div (327.8 + 460) = 0.1470$ and the available energy in *B.t.u.* $= 0.1470 \times 1006.3 = 147.9$ B.t.u.

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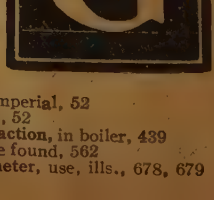

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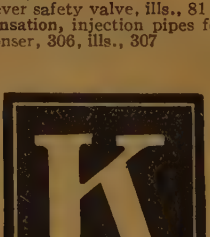

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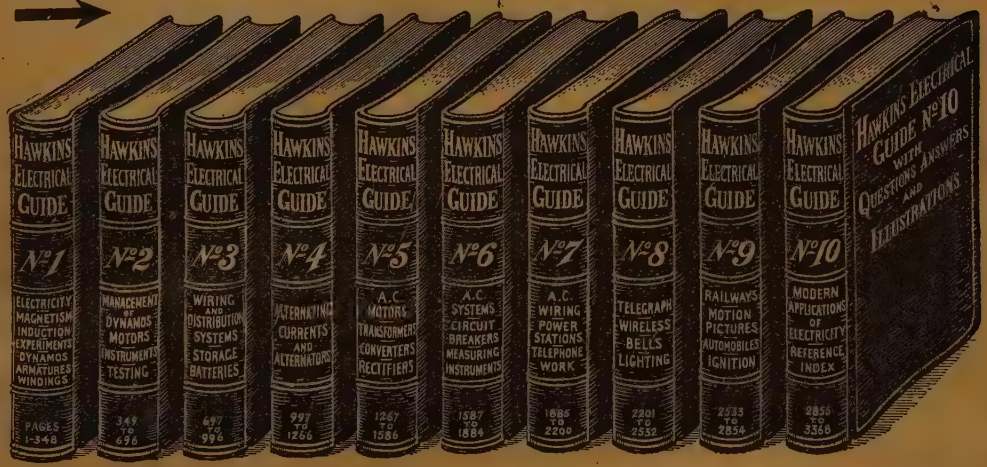

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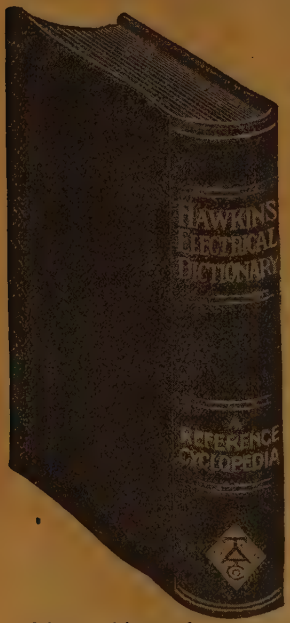

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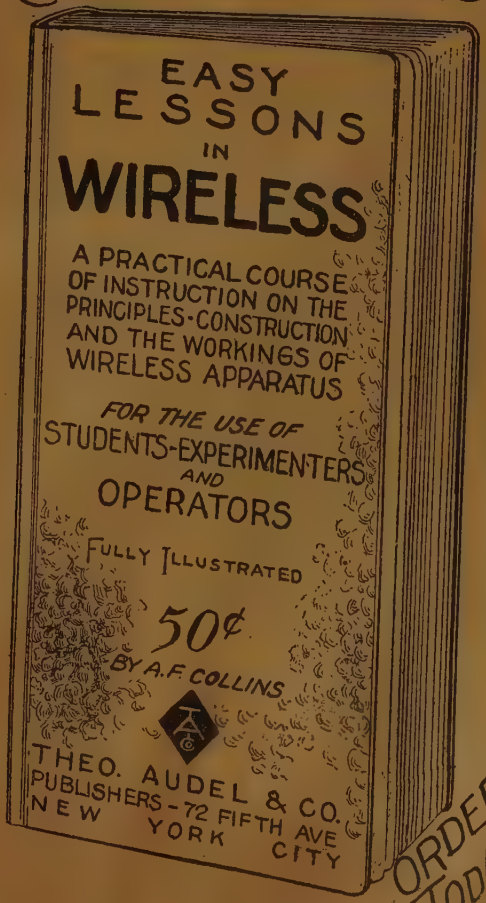

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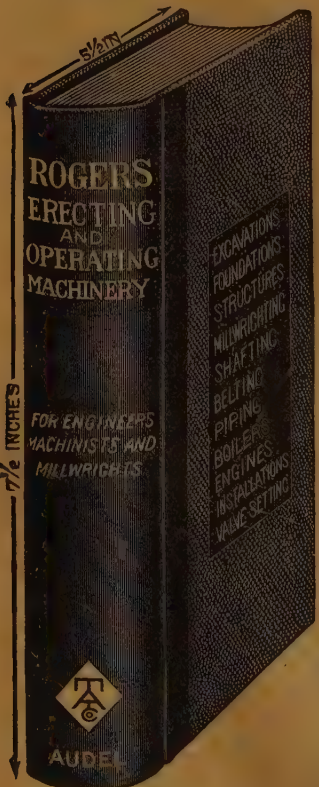

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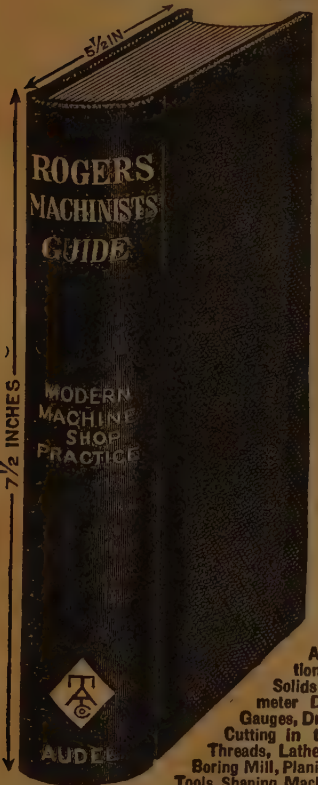

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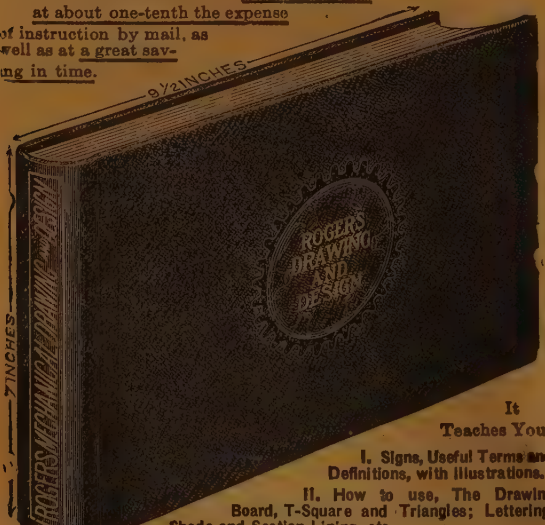

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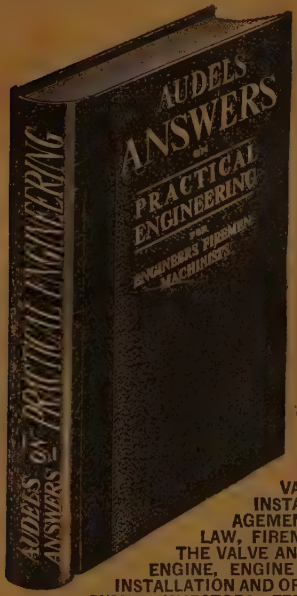

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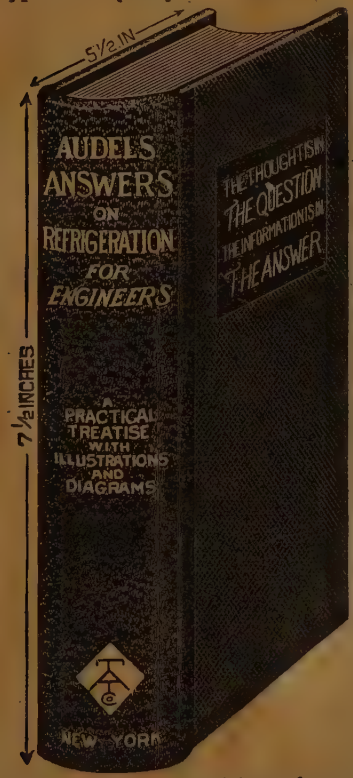

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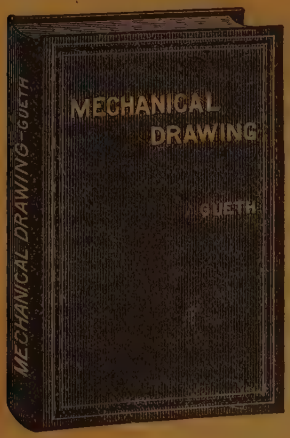

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This work is gotten up to fill a long-felt need for a practical book. It gives directions for running the various types of steam engines that are today in the market.

A partial list of subjects, which are fully, yet concisely presented follows:

Personal Introduction. The Steam Engine. Historical Facts Relating to the Steam Engine. Engine Foundations. The Steam Piston. Connecting Rods. Eccentrics. Governors. Materials. Workmanship. Care and Management. Lining up a Horizontal or Vertical Engine. Lining Shafting. Valve Setting. Condensers. Steam Separators. Air, Gas and Compressing Engines. Compounding. Arithmetic of the Steam Engine. Theory of the Steam Engine. Construction.

There are also descriptions of numerous types of the engines now in operation, such as the Corliss, Westinghouse and many others.

The book also treats generously upon the Marine, Locomotive and Gas Engines.

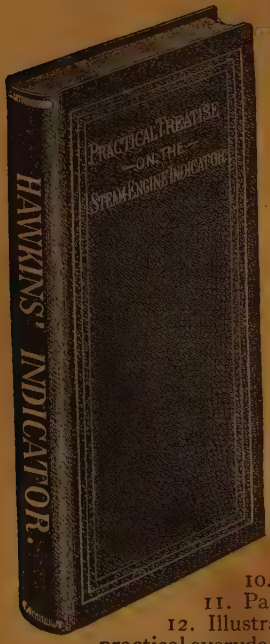
This is a rarely fine book, handsomely bound in green silk cloth, with full gold edges and titles; it contains 440 pages, 325 illustrations; in size it is 6x8¼ inches.

Price $2 Postpaid.

"ON INDICATOR CARDS," $1

Tells You How to Use an Indicator for Economical and Correct Steam Engine Operation, Written so You Can Understand.

THIS work is designed for the use of Erecting and Operating Engineers, Superintendents and Students of Steam Engineering, explaining, as it does, the economical use of steam.



This knowledge is necessary to the engineer, and constitutes a stepping-stone toward promotion or better conditions.

The following is a general outline of the subjects defined, fully illustrated, and presented most helpfully in the book:

1. Preparing the Indicator for Use.
2. Reducing Motions.
3. Piping up Indicator.
4. Taking Indicator Cards.
5. The Diagram.
6. Figuring Steam Consumption by the Diagram.
7. Examples of Diagrams.
8. Description of Indicators.
9. Measuring Diagram by Ordinates.
10. Planimeters.
11. Pantagraphs.
12. Illustrated with cards taken from practical everyday use, with clear and valuable lessons drawn from the diagrams; such as showing whether the valves are properly set or not.
13. Tables. 14. Ready Reference Index.

The book is handsomely bound in cloth, with titles and edges in gold, and is uniform in style with Hawkins' other books. Price $1 Postpaid.

HAWKINS' STEAM BOILER PRACTICE, $2

On the Intelligent and Economical Running of Steam Boilers and Appliances, a Valuable Book on Firing for all Power Users. Complete and Practical.

ENGINEERS comprise various grades from the chief engineer of some large establishment, who is usually an accomplished mechanic, to the mere stopper and starter, who is engineer by courtesy only, and whose place is likely to be soon filled by quite another man, so far as qualifications are concerned. Men ignorant of everything except the mere mechanical details of their work will soon have no place.

Read carefully this short extract from the "Introduction" to the volume:

SOLILOQUY OF AN ENGINEER. "Standing in the boiler-room and looking around me, there are many things I ought to know a great deal about. Coal! What is its quality? How much is used in ten hours or twenty-four hours.

Is the grate under the boiler the best for an economical consumption of fuel.

Can I, by a change in method of firing, save coal?

The Safety-valve. Do I know at what pressure it will blow off?

Can I calculate the safety-valve so as to be certain the weight is placed right?

Do I know how to calculate the area of the grate, the heating surface of the tubes and shell?

Do I know the construction of the steam-gauge and vacuum gauge?

Am I certain the steam gauge is indicating correctly, neither over nor under the pressure of the steam?

What do I know about the setting of boilers? About the size and quality of fire bricks?

About the combination of the carbon and hydrogen of the fuel with the oxygen of the atmosphere?

About oxygen, hydrogen and nitrogen? About the laws of combustion?

About radiation and heating surfaces?

Do I know what are good non-conductors for covering pipes, and why they are good? Do I know how many gallons of water in the boiler?

What do I know about water and steam? How many gallons of water are evaporated in twenty-four hours?

What do I know about iron and steel, boiler evaporation, horse-power of engines, boiler appendages and fittings?

Can I calculate the area and capacity of the engine cylinder? Can I take an indicator diagram and read it? Can I set the eccentric? Can I set valves?

Do I understand the construction of the thermometer, and know something about the pressure of the atmosphere, temperature and the best means for ventilation? Can I use a pyrometer?"

It is the purpose of this volume to answer all these enquiries, for the perfect knowledge of the operations carried on within the boiler-room involves an acquaintance with many branches of science.

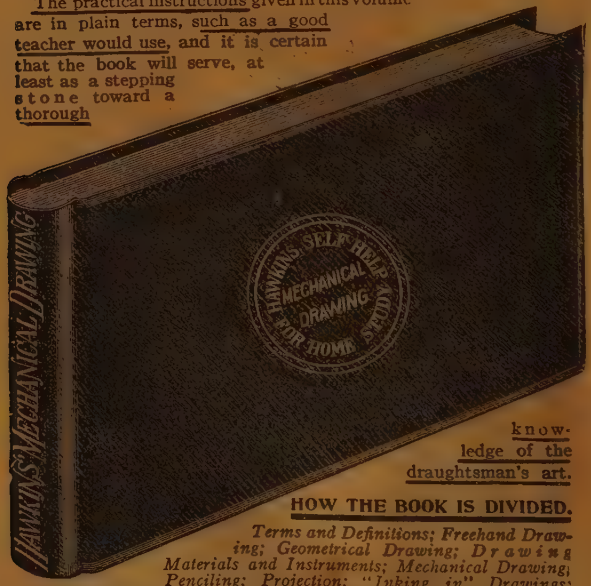
350 pages, 185 illustrations, good and very durable binding. Price $2.

MECHANICAL DRAWING, $2

This Book Gives the Basic Principles of this Art, Leading to the Complete Mastery of the Subject. Written So You Can Teach Yourself.

THE drawing-board and scientific book must go hand in hand with practical experience. One should not only be able to work practically, but he should be able to express his designs, improvements and inventions upon paper.

The practical instructions given in this volume are in plain terms, such as a good teacher would use, and it is certain that the book will serve, at least as a stepping stone toward a thorough knowledge of the draughtsman's art.



HOW THE BOOK IS DIVIDED.

Terms and Definitions; Freehand Drawing; Geometrical Drawing; Drawing Materials and Instruments; Mechanical Drawing; Penciling; Projection; "Inking in" Drawings; Lettering Drawing; Dimensioning Drawings; Shading Drawings; Section Lining and Colors; Reproducing Drawings; Drawing Office Rules; Gearing; Designing Gears; Working Drawing; Reading Working Drawings; Patent Office Rules for Drawings; Useful Hints and Points; Linear Perspective; Useful Tables; Purpose of the Work; Reference Index.

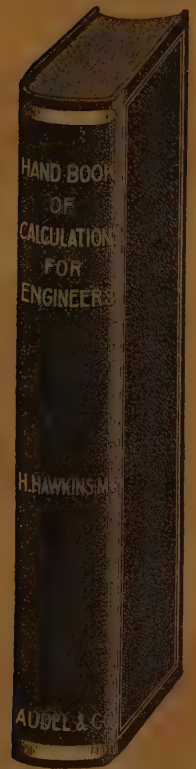
This book contains 320 pages and 300 illustrations, consisting largely of practical diagrams and drawings.

Bound in dark green cloth with gold edges; it is printed on fine paper, size 7 x 10 inches, and will make a valuable addition to any engineer's or mechanic's library.

Price $2 Postpaid.

HAWKINS' ENGINEERS' CALCULATIONS $2

It has been said to contain every Calculation, Rule and Table necessary to be known by the Engineer, Fireman and Steam User. Written so you can understand.



"I WOULD give a thousand dollars if I knew the principles upon which my engine works."

This was the remark of a western engineer made to a gentleman who was admiring the performance of the steam plant under the charge of the former. "I can attend to every necessary thing about my whole apparatus, engine, boilers, pumps, pipes, and do all that is expected of an engineer, but I don't know *why* the steam does its work, and I would give a thousand dollars *to know*."

Hand Book of Calculations is prepared for those, who, like the engineer whose words are quoted, wish *to know*, and are willing to pay the cost, in money and study.

It is a work of instruction and reference, being a complete course in Mathematics; all calculations are in plain arithmetical figures, so that the average man need not be confused by the insertion of the terms, symbols and characters to be found in works of so-called "higher mathematics."

It reminds you of the standard rules and formulas that you have forgotten, and which are always useful for an engineer to have at hand for ready reference.

IT EXPLAINS, WITH EXAMPLES, HOW TO FIGURE

The Steam Boiler; The Steam Pump, Horse Powers; How to Calculate for Engines and Boilers; Steam; Reference Tables of squares and cubes, square and cube roots, circumference and areas of circles; Tables of weights of metals and pipes; Tables of pressures of steam, horse power, etc., etc.

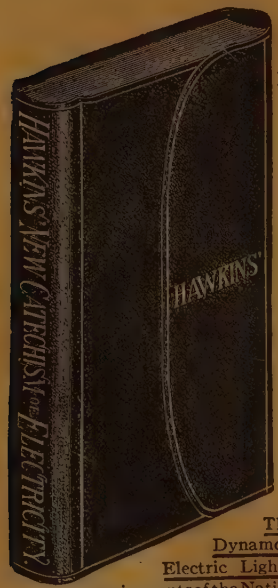
It explains the Mechanical Powers; Natural and Mechanical Philosophy; Strength of Materials; Mensuration; Arithmetic; Principles of Algebra and Geometry. Included are Tables of Weights, Measures Strength of Rope and Chains, Pressure of Water, Diameter of Pipes, etc.; The Indicator; The Safety Valve.

The work contains 330 pages and 150 illustrations; it is durably and handsomely bound. **Price $2 Postpaid.**

ELECTRICITY FOR ENGINEERS, $2

A Book easy to understand, Teaching all about Electrical Machinery and Appliances.

THIS work is addressed, not to the experimenter or to the toy maker, nor to the scholar, but to those who have to deal with Electricity as a part of their life work; to those who hold in check, like a powerful horse, and render serviceable to mankind, this mysterious force of nature.



One-third of the whole book is devoted to the explanation and illustration of the dynamo; and particular directions relating to its care and management — all the directions being given in the simplest way to assist, and not to confuse, the learner.

The names of the various parts of the machine are also given, with pictorial illustrations of the same.

The work is very complete, containing all the (book) information necessary for an intelligent man to take charge of a dynamo, or plant of any size.

The following is a list of the topics discussed and illustrated:

Conductors and Non-Conductors; Symbols, Abbreviations and Definitions relating to Electricity; The Motor; The Care and Management of the Dynamo and Motor; Electric Elevator; Electric Lighting; Wiring; The rules and requirements of the National Board of Underwriters in full; Electrical Measurements; Telephone and Telegraph Instruments; The Electric Railway; Line Work; Instructions and Cautions for Linemen and Dynamo Room; Storage Batteries; Care and Management of the Street-Car Motor; Electro Plating.

A book to aid the average man. It contains 550 pages with 300 illustrations of electrical appliances. It is bound in heavy red leather (size 4½ x 6¼, for the pocket), with full gold edges, and the most attractive hand-book ever printed and bound.

Price $2 Postpaid.

ALL ABOUT THE TELEPHONE, $1

A Valuable and Standard Guide for Telephone Engineers and Electricians. Written so you can understand.

THE "A B C of the Telephone" is a book valuable to all persons interested in this ever-increasing industry. No expense has been spared by the publishers, or pains by the author, in making this the most comprehensive handbook ever brought out relating to the telephone.

Fully Explained Under the Following 29 Chapter Headings.

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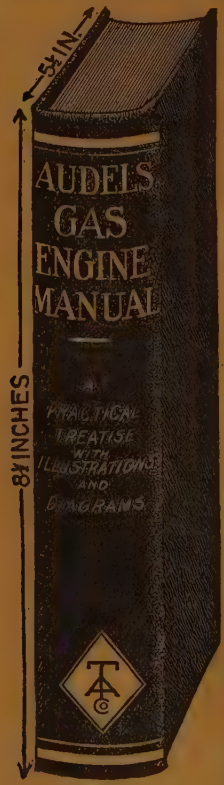
WITH READY REFERENCE INDEX

The volume contains 375 pages, 268 illustrations and diagrams; it is handsomely bound in black vellum cloth, and is a generously good book without reference to cost.

Price $1 Postpaid.

AUDELS GAS ENGINE MANUAL $2



THIS volume just published gives the latest and most helpful information respecting the construction, care and management of Gas, Gasoline and Oil Engines, Marine Motors and Automobile Engines, including chapters on Producer Gas Plants and the Alcohol Motor.

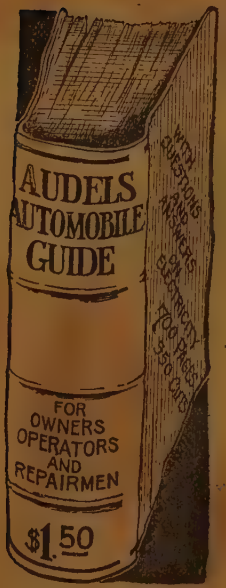
The work is divided into 27 Chapters as follows:—Historical Development — Laws of Permanent Gases—Theoretical Working Principles — Actual Working Cycles — Graphics of the Action of Gases — Indicator Diagrams of Engine Cycles — Indicator Diagrams of Gas Engines — Fuels and Explosive Mixtures — Gas Producer Systems — Compression, Ignition and Combustion — Design and Construction — Governing and Governors — Ignition and Igniters — Installation and Operation — Four-Cycle Horizontal Engines — Four-Cycle Vertical Engines — Four-Cycle Double-Acting Engines — Two-Cycle Engines — Foreign Engines — Oil Engines — Marine Engines — Testing — Instruments Used in Testing — Nature and Use of Lubricants — Hints on Management and Suggestions for Emergencies — The Automobile Motor — Useful Rules and Tables.

Each chapter is illustrated by diagrams which make it a thoroughly helpful volume, containing 512 pages, 156 drawings, printed in large clear type on fine paper, handsomely bound in rich red cloth, with gold top and title, measuring 5½ x 8½ inches and weighing over two pounds.

The book is a practical educator from cover to cover and is worth many times the price to any one using a gas engine of any type or size. **PRICE $2.00 POSTPAID**

AUTOMOBILE GUIDE $1.50

LATE—CONCISE—PRACTICAL



THE object of this book is to give, in the easiest understood form, the information necessary for the proper operation, care and maintenance of an automobile.

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Giving Just the Needed Information

WITH
Questions and Answers

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- Safety Valve Rules.
- Horse Power Rules.
- Theory and Elements of Engineering.
- Steam Tables.
- Marine Boilers.
- Oil Burners.
- Marine Engines.
- Turbines.
- Pumps and Condensers.
- Injectors and Heaters.
- Steering Engines.
- Pipes and Piping.
- Auxiliary Machines.
- General Care and Management, with Suggestions.
- Breakdowns and Repairs at Sea.
- Overhauling and Laying Up.
- Gasoline Engines.
- Gas Producers.
- Heavy Oil Engines.
- Diesel Engines.
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